**PhD Programme in Heritage Science**
**Curriculum 2: Science and Technologies for the Architectural Heritage**

Sapienza University of Rome
Leader University: Politecnico di Milano
Curriculum Coordinator: professor Renata Picone

XXXVIII PhD cicle

# A Climate-sensitive Methodology for the Sustainable Protection of Historic Villages in a Changing Climate.

## An Exploratory Application to Osidda (Sardinia, Italy)


**Tutor**
**Professor Valeria Natalina Pracchi**

**Co-tutors**
**Professor Donatella Rita Fiorino**
**Professor Simone Ferrari**

**Candidate**
**Giulia Cherchi**


a.a 2024/2025

DIPARTIMENTO
DI SCIENZE DELL'ANTICHITÀ

SAPIENZA
UNIVERSITÀ DI ROMA

POLITECNICO
MILANO 1863

# PHD PROGRAMME OF NATIONAL INTEREST IN HERITAGE SCIENCE

*Sapienza University of Rome, Department of Science of Antiquity*
*National Coordinator: Professor Paolo Carafa*

**CICLE XXXVIII**

**Curriculum 2:** Science and Technologies for the Architectural Heritage.

Leader University: *Politecnico di Milano*
Coordinator: *Professor Renata Picone*

# A Climate-sensitive Methodology for the Sustainable Protection of Historic Villages in a Changing Climate.
## An Exploratory Application to Osidda (Sardinia, Italy)

Scientific Disciplinary Sector:
CEAR-11/B – Conservation


**Tutor:**
Professor Valeria Natalina Pracchi
**Co-tutors:**
Professor Donatella Rita Fiorino
Professor Simone Ferrari

**Candidate:**
Giulia Cherchi
2079520

*Politecnico di Milano*
*Department of Architecture, Construction Engineering and Built Environment*


*a.a 2024/2025*

**Doctoral research funded by the European Union**

Next Generation EU

Mission: 4

Component: 1

Doctoral scholarship: F ALTRI FINANZIAMENTI Patrimonio architettonico e transizione green: interventi compatibili e criteri di valutazione, finanziata da Politecnico di Milano

In collaboration with: University of Cagliari
University College Dublin

Università degli Studi di Cagliari

UCD DUBLIN

Finanziato dall'Unione europea NextGenerationEU

Italiadomani
PIANO NAZIONALE DI RIPRESA E RESILIENZA

Ministero dell'Università e della Ricerca

## Table of Contents

**Abstract in English**
**Abstract in italiano**
**Preface**
**Introduction.** Current Challenges Facing Historic Villages..... **p. 1**

**Part 1.** Architecture, Landscape, and Environmental Issues in the Context of Historic Villages: Theoretical Background and State of the Art

**Chapter 1.** Traditional and Contemporary Cultural Approaches and Policies for Italian Historic Centres and Villages..... **p. 6**

**1.1** Historic Centres within the Italian Planning System: Institutional Competences, Regulatory Tools, and Evolving Values..... **p. 7**

**1.1.1** The Evolution of Planning and Conservation Frameworks in Post-war Italy..... **p. 7**

**1.1.2** Landscape as Cultural Identity: the 21st-Century Shift in Italian Policy and Planning..... **p. 14**

**1.2** The Issue of Small Historic Villages and Inner Areas in the 21st Century..... **p. 19**

**1.2.1** Historical Marginalisation and Emerging Cultural Values of Italian Inner Areas..... **p. 20**

**1.2.2** A Comparative European Frame for Inner Areas and Small Settlements..... **p. 23**

**1.2.3** Italian Territorial Cohesion Policies for Inner Areas and Small Settlements..... **p. 28**

**1.3** Legal Framework and Policies for Conservation and Interventions in Historic Villages in Sardinia..... **p. 34**

**1.3.1** Laws, Plans, and Instruments: a Framework for Historic Centres in Sardinia..... **p. 34**

**1.3.2** Implementation in Practice: Programmes, Funding Cycles, and Inner-Area Strategies..... **p. 38**

**1.4** The Semantics of the Term *borgo* and its Aesthetic Misconception..... **p. 43**

**Chapter 2.** Historical Architecture and Environmental Context: Traditions, Challenges, and New Perspectives..... **p. 46**

**2.1** The Influence of Climate on Historic Urban Shape and Architecture: Lessons from Tradition..... **p. 47**

**2.1.1** Climate-Specific Typologies and Operational Lessons..... **p. 50**

**2.1.2** Climatic and Morphological Variations in Traditional Settlements of Sardinia..... **p. 57**

**2.2** From Post-War Development Pressures and Landscape Deterioration to a New Environmental Awareness in Architectural and Urban Culture..... **p. 63**

**2.3** Heritage as a Non-Renewable Resource and the Concept of Sustainability..... **p. 71**

**2.3.1** The "Fourth Pillar" of Culture: Convergences Between Conservation and Sustainability..... **p. 72**

**2.3.2** Integrating Cultural Heritage into Climate Action..... **p. 76**

**2.4** The Relevance of Community Involvement in Sustainable Development and Conservation Processes..... **p. 78**

**2.4.1** Community Participation as an Integral Element of Heritage Care **p. 79**

**2.4.2** Community Resilience and Participation in Sustainable Development Processes..... **p. 82**

**Chapter 3.** Historic Architecture and Contemporary Environmental Challenges: Theoretical Approaches, Policies, and Operational Models..... **p. 86**

**3.1** The Effects of Climate Change in the Mediterranean Area and the Region of Sardinia..... **p. 87**

**3.2** European and Italian Legislation Towards More Sustainable Urban Environments..... **p. 94**

**3.2.1** European and Italian Regulatory Evolution..... **p. 94**

**3.2.2** Renewable Energy Sources and Renewable Energy Communities **p. 99**

**3.2.3** Regional Implementation: Sardinia and Territorial Energy Instruments..... **p. 102**

**3.3** Conflicts and Challenges Between the Green Transition and Historic Landscape Protection..... **p. 105**

**3.3.1** Sustainability Discourse and Greenwashing in the Built Environment..... **p. 105**

**3.3.2** Limits of Current Operational Approaches to Retrofit in Mediterranean and Sustainable Heritage Contexts..... **p. 107**

**3.3.3** Methodological Approaches and Perspectives for Sustainable Built Environments..... **p. 110**

**Part 2.** Protocol of Analysis and Stategy Development for Climate-Sensitive Urban Interventions in Historic Villages: Methodological Framework and Case Study Application

**Chapter 4.** A Methodological Framework: Strategies and Tools for Designing Environmental Quality..... **p. 114**

**4.1** Toolkit and Pillars for the Development of the Methodology **p. 115**

**4.1.1** The Urban Microclimate..... **p. 115**

**4.1.2** The Climate-Environmental Components..... **p. 116**

**4.1.3** The Urban Heat Island Phaenomenon (UHI)..... **p. 119**

**4.1.4** Thermo-hygrometric comfort..... **p. 122**

**4.2** Towards an Integrated Approach to the Historic Urban Fabric: the Microclimate and Outdoor Thermal Comfort Research Field **p. 125**

**4.2.1** Outdoor Microclimate Assessment in Existing and Historic Urban Contexts: A Literature Review on Influencing Factors..... **p. 127**

**4.2.2** Guidelines for Urban Microclimate and Planning: Pioneering Examples Worldwide..... **p. 133**

**4.3** The Urban Microclimate Design (UMD) for Heritage and Climate-Oriented Approaches..... **p. 138**

**4.4** The Interdisciplinary Analytical Phase..... **p. 141**

**4.4.1** The Heritage Context Analysis and Monitoring: Methods, Software, and Tools..... **p. 141**

**4.4.2** The Microclimate Modelling and Assessment: Methods, Software, and Tools..... **p. 149**

**4.5** The Design Phase: Strategies and Solutions for Outdoor Thermal Comfort Enhancement..... **p. 155**

**Chapter 5.** The Case Study of the Historic Village of Osidda..... **p. 162**

**5.1** Choice of the Case Study..... **p. 164**

**5.2** Historical, Landscape, and Urban Context..... **p. 167**

**5.2.1** History, Environmental Characteristics, and Population..... **p. 167**

**5.2.2** The Urban Centre: Structure, Architecture, Constructive Culture..... **p. 173**

**5.3** The Heritage Context Analysis: Knowledge and Interpretation **p. 191**

**5.3.1** Development, Structure, and Thematic Layers of the Georeferenced Database..... **p. 191**

**5.3.2** The Stratigraphic Analysis..... **p. 223**

**5.3.3** Results and Interpretation of the GIS-based Analysis..... **p. 231**

**5.3.4** From Local GIS Data to the National "*Carta del Rischio*"..... **p. 236**

**5.4** The Urban Microclimate Analysis: Modelling and Assessment **p. 238**

**5.4.1** Urban Models, Meterological Data Analysis, and Preparation for the Urban Microclimate Simulations..... **p. 238**

**5.4.2** Summer Urban Microclimate Simulations Results..... **p. 245**

**5.4.3** Supplementary Experimental Analysis..... **p. 254**

**5.5** The Design Phase: One Possible Operative Application of the Study..... **p. 264**

**Discussion.** Towards Possible Operational Guidelines for Climate-Conscious Urban Interventions in Rural Historic Villages **p. 269**

**Conclusions**..... **p. 274**

**Attachments**

**Attachment 1.** Carta del Rischio. Example of a Completed Form - Via Mazzini, Osidda

**Attachment 2.** ENVI-met Materials and Vegetation Database

**Attachment 3.** Hourly PMV Record of the Simulated Summer Typical Critical Days

**Attachment 4.** Urban Microclimate Simulations Outcomes. Comparative Analysis

**Attachment 5.** Plaster parametric simulations

**Attachment 6.** Computational parameters and time of the simulations

**Thematic Bibliography**

**Acknowledgements/Ringraziamenti**

## Abstract in English

This thesis addresses the growing pressures on the historic fabric and cultural heritage of small inland villages in Sardinia, a wide and structurally significant component of the regional settlement system, where long-term demographic decline has reduced everyday use, care, and routine maintenance, while climate change is increasing thermal stress and related environmental risks. These settlements remain identity-rich environments that support community cohesion and local knowledge, yet they are often protected through aesthetic approaches that rarely translate into operational tools capable of guiding adaptation to emerging environmental stresses. The research responds to this gap between conservation-driven protection and climate-driven transformation by developing and testing a climate-sensitive conservation protocol at the scale of the whole settlement, with particular attention to outdoor thermal comfort.

The study adapts the Urban Microclimate Design (UMD) approach, originally developed for new urban development, to the assessment and design of interventions in existing historic villages in the Mediterranean climatic zone. The protocol integrates architectural and landscape analysis, GIS-based spatial diagnostics, and ENVI-met microclimatic simulations to identify site-specific mitigation strategies that are compatible with heritage values, materials, and spatial logic. The method is applied to Osidda (north-eastern Sardinia), a compact hilltop village that provides a representative test-bed due to its morphology, landscape setting, and demographic contraction.

The thesis delivers a replicable methodological workflow and a set of strategies supported by analysis and results, climate-oriented and compatible with conservation translating microclimatic evidence into guidance that can support municipal planning and local design processes in small historic settlements. While calibrated for Mediterranean conditions and the specific parameters of Osidda, the workflow is designed to be transferable provided that local climate data and settlement characteristics are re-specified. Beyond the single-building scale, the village is interpreted as a complex urban organism in which microclimate, cultural significance, everyday practices, and territorial dynamics must be addressed together.



**Keywords**: historic villages; heritage conservation; urban microclimate; outdoor thermal comfort; climate change; Sardinia.



## Abstract in italiano

La presente tesi indaga le crescenti pressioni sul tessuto storico e sul patrimonio culturale dei piccoli borghi dell'entroterra sardo, parte ampia e strutturante del sistema insediativo regionale. Il declino demografico di lungo periodo ha progressivamente ridotto l'uso quotidiano degli spazi, la cura e la manutenzione ordinaria, mentre il cambiamento climatico intensifica lo stress termico e i rischi ambientali correlati. Pur restando luoghi ad alta densità identitaria, capaci di sostenere coesione sociale e saperi locali, questi insediamenti sono spesso tutelati attraverso approcci prevalentemente estetici, che faticano a tradursi in strumenti operativi in grado di orientare l'adattamento alle nuove condizioni ambientali. A partire da questo scarto tra tutela del patrimonio e necessità poste dal cambiamento climatico, la ricerca sviluppa e sperimenta un protocollo di conservazione sensibile al clima alla scala dell'intero insediamento, con particolare attenzione al comfort termico esterno.

Lo studio adatta l'approccio dell'Urban Microclimate Design (UMD), nato per la progettazione di nuovi assetti urbani, alla valutazione e alla definizione di interventi nei borghi storici del contesto climatico mediterraneo. Il protocollo integra analisi architettonica e paesaggistica, diagnosi spaziali supportate da strumenti GIS e simulazioni microclimatiche mediante ENVI-met, al fine di individuare strategie di mitigazione specifiche per il sito, compatibili con i valori di tutela, i materiali e la logica spaziale dei luoghi. Il metodo è applicato a Osidda (Sardegna nord-orientale), un compatto borgo collinare scelto come caso studio per le sue caratteristiche morfologiche, l'assetto paesaggistico e la contrazione demografica.

La tesi restituisce un percorso metodologico replicabile e un insieme di strategie supportate da analisi e risultati, orientate al clima e compatibili con il restauro, traducendo i risultati microclimatici in indicazioni operative a supporto della pianificazione comunale e dei processi progettuali nei piccoli insediamenti storici. Pur essendo calibrato sulle condizioni mediterranee e sui parametri specifici di Osidda, il protocollo è concepito per essere applicabile ad altri contesti, a condizione che vengano ricalibrati i dati climatici e le caratteristiche locali. Oltre la scala del singolo edificio, il borgo è interpretato come un organismo urbano complesso, in cui microclima, significato culturale, pratiche quotidiane e dinamiche territoriali devono essere affrontati in modo integrato.



**Parole chiave**: borghi storici; conservazione del patrimonio; microclima urbano; comfort termoigrometrico esterno; cambiamento climatico; Sardegna.

# Preface

This thesis is grounded in a longstanding interest in the relationship between historic settlement form, landscape, and the environmental conditions that enable everyday life, formed throughout my academic background in architectural conservation. As a Sardinian researcher, I have also been closely familiar with the condition of inland villages on the island and with the everyday implications of demographic decline and uneven access to services.
The initial impulse for this doctoral project emerged before the PhD, during a short research fellowship at the University of Cagliari, School of Conservation, focused on the municipality of Osidda. The fellowship, titled "Study of the macro-components of the historical landscape (settlements; architectural emergencies; archaeological sites) of the Municipality of Osidda", formally had a four-month duration. In practice, it centred on building a GIS database and documenting architectural characteristics across the village's building units. The experience provided more than a dataset: it offered a close understanding of how heritage values, spatial patterns, and everyday use intersect in a small inland settlement, and it highlighted the practical limits of documentation and protection when they remain disconnected from questions of use and long-term management.
Building on that groundwork, the doctoral research did not simply continue the fellowship's scope. It developed a broader set of questions that brought environmental change and settlement liveability to the foreground, using outdoor microclimatic conditions and thermal comfort as a lens to read the village at a comprehensive scale. In this sense, the early work helped to shape the direction of the PhD, and to clarify the need for conservation to evolve from descriptive protection towards a method that supports concrete decisions under emerging climatic pressures. Osidda was subsequently confirmed as a suitable case study because it offers a representative combination of factors that are critical to the research: compact morphology, a clear relationship with the surrounding landscape, and the demographic contraction typical of many inland villages in Sardinia. The earlier fellowship ensured a more informed point of departure for the knowledge phase of the protocol, allowing the doctoral research to devote greater attention to method development, simulation-based testing, and the refinement of operational guidance rather than repeating preliminary documentation from scratch.
Over the course of the research, it became increasingly clear that the challenges facing historic villages, especially in the contemporary time of crisis and transition, cannot be addressed through a single disciplinary lens. Conservation approaches, when framed mainly through aesthetic categories, risk treating villages as static images rather than as inhabited systems. Conversely, climate and environmental agendas, when applied through generic technical templates, risk proposing solutions that do not fit the logic of historic materials, morphologies, and regulatory constraints. The work presented here is shaped by the need to keep protection and transformation in productive alignment through an operational and evidence-based approach. In this respect, outdoor microclimatic assessment provides a useful perspective: it supports settlement-scale reasoning beyond the single building and links environmental performance to everyday life. This shift was also supported by the research environment at the University of Cagliari, where outdoor comfort and microclimatic assessment are addressed through the discipline of hydraulic engineering. Within this context, I was able to find the technical expertise and support needed to strengthen the environmental component of the research and to integrate it with a conservation-based reading of the village.
A further turning point in the development of the thesis was an overseas research period in Dublin, where heritage management is being reframed under the concurrent pressures of climate change and a housing crisis. This experience did not provide a model to be transferred directly to Sardinia, but it clarified two principles that informed the direction of the research. First, the long-term care of small settlements also depends on the agency of local communities, whose everyday practices and forms of stewardship shape maintenance cycles and the use of space. Second, even where policy frameworks appear advanced, they remain ineffective if they are not translated into operational tools that local administrations and design teams can apply in concrete decision-making. These insights reinforced the need to move beyond general recommendations towards a methodological protocol that links diagnosis, simulation, and design choices in a transparent workflow.
The thesis is written with a double intention. It contributes to ongoing debates on conservation as a form of climate action, and it develops a workflow that can be used in practice. By adapting the Urban Microclimate Design approach to historic villages, and integrating architectural and landscape analysis with GIS-based diagnostics and ENVI-met simulations, the research aims to translate microclimatic evidence into guidance that can support municipal planning and conservation practice, with outdoor thermal comfort as a key indicator of liveability.
Throughout the thesis, references are provided wherever statements are derived directly from established literature. Where footnotes are absent, the text reflects original analytical interpretations and methodological reasoning developed in this study, informed by the reviewed literature and by the empirical work carried out.
Finally, this Preface is intended to clarify the experiences that informed the perspective of the study. The Introduction that follows outlines the research context, the gap addressed, and the methodological approach that frames the chapters.





# Introduction.
# Current Challenges Facing Historic Villages

Across Italy, and particularly in regions with a strong inland settlement network, small historic villages constitute a widespread component of the territorial structure and an important repository of cultural landscapes, building traditions, and local knowledge. Their historic cores are not only valuable artefacts, but also places where everyday life has long been organised through spatial patterns, climatic adaptations, and shared practices of use and care. In many inland and marginal areas, however, this relationship has been progressively weakened since the mid twentieth century[1]. Alongside long-term demographic decline and population ageing, processes of modernisation and the diffusion of new building techniques, infrastructures, and domestic standards have altered ways of inhabiting and maintaining the existing fabric. Reduced everyday use of buildings and open spaces, together with thinning maintenance cycles, has accelerated material decay and increased the fragility of public and private assets. This condition affects a substantial share of the Italian territory and involves thousands of municipalities, many of them with fewer than 5,000 inhabitants[2]. In such contexts, the future of historic villages (in Italian commonly referred to as *borghi*) is closely linked to questions of territorial cohesion, accessibility to services, and the continuity of community life.

At the same time, many of these settlements retain a remarkably legible historic fabric, preserving building traditions, materials, and spatial patterns that constitute a tangible record of past ways of inhabiting, producing, and shaping the landscape. These villages can therefore be described as identity-rich environments, as they often sustain forms of belonging and social cohesion that exceed their demographic size[3]. Their erosion entails not only the loss of built heritage, but also a weakening of cultural continuity, the transmission of local knowledge, and the capacities for long-term stewardship that have historically maintained these places[4].

Alongside demographic contraction, historic villages are increasingly exposed to climate-related pressures. Mediterranean climate projections point to higher temperatures, more frequent and intense heat episodes, longer dry periods, and a greater incidence of short, intense rainfall events[5]. In heritage settings characterised by compact morphologies and high thermal mass materials these trends can translate into growing thermal stress and related environmental pressures. The issue is not only the physical performance of buildings in isolation, but the environmental quality of the

1 Carozzi, Mioni 1970; Mortara 1970.

2 ANCI 2019.

3 Barca *et al.* 2014.

4 Sanna 2009a; Kealy 2020.

5 CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici n.d.

settlement as a whole, including the conditions that shape everyday outdoor use and comfort at settlement scale[6].

In this study, the Mediterranean climatic zone is treated as a specific field where the relationship between settlement form and climate has historically been strong, and where current shifts are particularly disruptive[7]. Within this frame, Sardinia offers a clear case: many villages have retained recognisable historic fabrics and climate-tuned construction logics, yet they face increasing exposure to heat stress, drought, and episodic extreme rainfall[8]. In this context the question of climate-sensitive conservation is especially urgent.

In recent decades, planning and heritage instruments have expanded the protection of historic cores, including in inner areas. However, protection has often privileged visual integrity and formal coherence, without translating into operational guidance for adaptation[9]. In parallel, climate and energy agendas have largely relied on building-scale measures derived from contemporary construction logics, which are not always compatible with historic materials and morphologies[10]. The present thesis stems from this gap: its central assumption is that, to achieve the long-term continuity of historic villages, a climate-conscious, conservation-aware approach capable of informing concrete choices at the settlement scale is required.

The research focuses on the settlement scale, treating the historic village as a complex urban organism in which morphology, materials, vegetation, and patterns of use interact with local climatic conditions. Within this focus, outdoor microclimatic conditions and thermal comfort are adopted as a diagnostic and decision-support lens. This choice is not intended to reduce the problem to a single performance metric, but to provide a concrete entry point through which environmental evidence can be linked to heritage-compatible design strategies and to municipal decision-making.

The aim of the thesis is to develop and test a climate-sensitive conservation protocol for Mediterranean historic villages that integrates conservation principles with microclimatic assessment and that can be applied within municipal planning and conservation processes.

The research is guided by the following questions:

- How can a settlement-scale protocol integrate heritage values, spatial constraints, and microclimatic evidence into a coherent workflow that supports decisions under emerging climatic pressures?

- Which morphological, material, and vegetation-related factors most influence local microclimatic conditions in a compact Mediterranean historic village?

6 Vitiello 2012.

7 IPCC 2022.

8 Sanna 2009b; Autonomous Region of Sardinia 2024a.

9 Barbera *et al.* 2022.

10 Mazzarella 2015; MiBACT 2015.





- To what extent can heritage-compatible mitigation measures improve outdoor thermal comfort, and how can their effectiveness be evaluated?

To address these questions, the thesis pursues three objectives:

- To develop a structured, settlement-scale protocol that integrates conservation principles with microclimatic assessment and produces operational guidance.

- To identify the main settlement-scale drivers of local microclimatic conditions through integrated architectural, landscape, and GIS-based diagnostics, supported by microclimatic simulation.

- To test and compare heritage-compatible mitigation scenarios and translate results into decision-support outputs that can inform planning and project processes.

The thesis adapts the Urban Microclimate Design approach, originally developed for new urban development, to the assessment and design of interventions in existing historic villages. The protocol combines a knowledge and diagnostic phase with a design and testing phase. It integrates architectural and landscape analysis, GIS-based spatial diagnostics, and ENVI-met microclimatic simulations to identify and evaluate site-specific mitigation strategies that are compatible with heritage values, materials, and spatial logic.

The workflow is conceived to be replicable, while recognising that applications must be recalibrated through local climate data and settlement characteristics.

The protocol is tested through the case study of Osidda, a compact hilltop village in north-eastern Sardinia. Osidda is selected because it concentrates key conditions relevant to the research, including a recognisable historic morphology, a clear relationship with its landscape setting, and demographic contraction typical of many inland villages.

The thesis is organised in two parts, a theoretical and critical framework (Chapters 1-3), contextualising the research, and an operational and experimental section (Chapters 4-5). Chapter 1 reviews key cultural approaches, policies, and regulatory tools for historic centres and villages in Italy and Sardinia, including the implications of the contemporary "*borgo*" discourse. Chapter 2 examines the relationship between historic architecture and environmental context, focusing on how climate-tuned traditions are being challenged by current transitions and by the sustainability debate. Chapter 3 outlines emerging policies and operational practices for climate-related challenges in heritage contexts, highlighting both promising directions and unresolved tensions. Chapter 4 presents the proposed methodological protocol, detailing its workflow and tools. Chapter 5 applies the protocol to Osidda, reporting diagnostic findings, simulation results, and the evaluation of mitigation scenarios as a basis for operational guidance.

# Part 1.

## Architecture, Landscape, and Environmental Issues in the Context of Historic Villages: Theoretical Background and State of the Art

# Chapter 1.
# Traditional and Contemporary Cultural Approaches and Policies for Italian Historic Centres and Villages

From the 1930s to the early 2000s, scholarly debate and institutional action on historic centres developed through successive phases, progressively refining conservation aims and tools. Over time, however, the challenges facing these contexts have diversified, and a growing divergence has emerged between major historic centres and smaller settlements and historic villages, often located in rural and marginal areas. In the latter, demographic contraction, reduced maintenance, and limited access to services intersect with the need to safeguard historically stratified fabrics and landscape relationships.

Against this background, legislative frameworks, policy programmes, and cultural discourses have gradually shifted from a predominant focus on historic centres to a more explicit concern for historic villages. Alongside the recognition of their historical and landscape value, attention has increasingly turned to questions of settlement liveability and to the relationship between the quality of the built environment and everyday practices. At the same time, despite the formal move beyond purely aesthetic paradigms, approaches centred on visual integrity and material permanence continue to shape both political narratives and regulatory practices, sometimes with limited operational support for addressing social and environmental pressures.

In Sardinia, as in comparable contexts, strategies concerned with environmental conditions and comfort are increasingly discussed not only in terms of risk reduction, but also in relation to the continuity of use and care of the existing building stock. Before examining environmental, ecological, and energy-related questions in detail, it is therefore necessary to clarify the national and regional visions concerning historic centres and, in particular, minor settlements. This chapter reviews the evolution of Italian approaches to historic centres, introduces the contemporary framing of historic villages and inner areas, and briefly situates the Italian debate within a European comparative perspective. It then discusses current policy instruments for inner areas and outlines the regulatory framework that governs interventions in historic urban fabrics, in order to identify both opportunities and constraints that shape implementation.

Clarifying this context is essential for the research because the proposed protocol is intended to be applicable within real planning and conservation processes, rather than as an abstract methodological exercise. Policy agendas and regulatory instruments shape what can be done in historic fabrics, which priorities are recognised, and which forms of evidence are considered actionable in decision-making. By identifying where current frameworks remain descriptive or primarily form-driven, this chapter helps to define the operational gap that the thesis addresses through a settlement-scale, climate-sensitive conservation workflow.





## 1.1. Historic Centres within the Italian Planning System: Institutional Competences, Regulatory Tools, and Evolving Values

The Italian planning system has long faced the challenge of governing a highly complex territorial framework. On the one hand, it must manage an extensive cultural heritage embedded in layered historic fabrics and in landscapes that are widely recognised for their cultural value. On the other hand, planning regulations apply across almost eight thousand municipalities, ranging from small villages to large metropolitan areas, with markedly different social, cultural, and economic conditions[1]. For these reasons, Italy was among the earlier European contexts to confront the question of historic centres through planning theory, institutional competences, and regulatory tools[2]. Over time, however, the recognition of the city as a living and evolving environment has brought to the foreground a persistent tension between conservation imperatives and the demands of contemporary change. This tension is reflected in fragmented competences and instruments, and in what has been described as a "*fundamental dualism in the underlying analytical approach*"[3], which has often made it difficult to reconcile protection aims with operational planning practice[4].

### 1.1.1 The Evolution of Planning and Conservation Frameworks in Post-war Italy

To this day, Italian planning legislation remains anchored to the Fundamental Planning Law of 1942, which is still in force more than eighty years later. The law established a hierarchical structure, from Territorial Coordination Plans (TCPs)[5] to municipal master plans called General Development Plans (GDPs)[6] and Detailed Plans for implementation (DPs)[7], intended to connect

1 Hine 1993; Scattoni, Falco 2011, p. 5.

2 Atzeni *et al.* 2022, p. 1.

3 Angiuli 2015, p. 1.

4 *Ivi*, pp. 1-2.

5 Italian Government 1942, articles 5 and 6. The Territorial Coordination Plan (*Piano Territoriale di Coordinamento*) was the main territorial coordination instrument intended to coordinate development strategies, infrastructure, and land uses across a wider area (often implemented at provincial or regional scale in later practice).

6 *Ivi*, articles 7, 8, 9 and 10. At municipal level the law introduced the General Development Plan (*Piano Regolatore Generale*), defining land-use designations, building-density limits, developable and non-developable areas, protected zones, and infrastructure provisions.

7 *Ivi*, articles 13, 14, 15, 16 and 17. At local level the law relied on Detailed Plans (*Piani Particolareggiati*) as implementation instruments regulating subdivision, alignment, and construction details in accordance with the municipal plan.

broader spatial strategies with local interventions across the whole municipal territory.

Although frequently described as rigid when measured against contemporary socio-economic conditions, the 1942 law introduced important innovations compared to earlier preservation-oriented legislation. Its structure offered a coherent sequence from general territorial strategies to local implementation across the municipal territory, allowing pre-existing urban patterns, including historically stratified fabrics, to enter the planning frame, although without providing tailored operational guidance for historic centres. By treating the city and its territory as an integrated planning object, it moved beyond approaches that defined heritage primarily through monument-based or visually delimited categories, as in the 1939 Bottai Laws[8], which still described heritage as "*groups of immovable objects that form a characteristic aspect with aesthetic and traditional value*"[9].

Within the cultural debate of the period, Gustavo Giovannoni, president of the National Institute of Urban Planning in the 1930s, played an influential role in shaping the broader intellectual framework in which the law took form, even though he did not participate directly in drafting it. His proposal to extend protection from the monument to its wider urban and landscape setting anticipated later notions of context and cultural landscape[10]. Yet, in institutional and procedural terms, the law left significant ambiguities unresolved. While it allocated key responsibilities for plan preparation and approval to different levels of government, it did not specify technical guidelines or operational procedures capable of supporting implementation[11]. In the early post-war period, this gap contributed to a contradictory outcome: comprehensive plan-making advanced slowly, while urgent reconstruction needs and housing demand were frequently addressed through "special" plans, often drafted and approved rapidly, and therefore only partially aligned with the systematic intent of the 1942 framework[12].

Between 1954 and 1960, the Ministry of Public Works issued a list of municipalities required to draft a GDP, including major urban centres as well as smaller towns recognised for their environmental and historical significance[13]. In parallel, the Gubbio Charter (1960) stressed the need to identify and delineate historic centres systematically across the national territory, treating

8 Italian Government 1939a; Italian Government 1939b.

9 Italian Government 1939b, article 1, paragraph 1, item 3.

10 Giovannoni 1928.

11 Scattoni, Falco 2011, pp. 13-14.

12 *Ivi*, pp. 17-20.

13 *Ivi*, pp. 20-21.





their formal recognition as a prerequisite for effective planning[14]. It called for their integration into GDPs and for the preparation of dedicated DPs, notably Conservative Recovery Plans[15]. In this way, the Charter helped consolidate a shift away from approaches focused mainly on the material preservation of heritage and towards a broader understanding of the historic centre as part of a living urban system. Development and conservation were increasingly framed as potentially complementary objectives, and the historic centre was presented not only as a cultural artefact but also as a resource whose vitality could contribute to territorial organisation and planning strategies.

Despite this evolution in discourse and principles, the institutional framework for safeguarding historic urban centres remained uncertain. A persistent question concerned whether responsibility should primarily rest within cultural heritage administration, through the Superintendencies[16], or within urban planning instruments, highlighting the hybrid nature of historic centres as a category of heritage[17]. Superintendencies traditionally exercised protective authority over listed buildings, yet their role in relation to historic centres as urban ensembles remained ambiguous even after the 1942 law[18].

In response to these uncertainties, in 1964 the government established the Commission of Inquiry for the Protection and Enhancement of the Historical, Archaeological, Artistic, and Landscape Heritage (the Franceschini Commission)[19]. After reviewing heritage legislation alongside prevailing planning norms, the Commission set out principles intended to support a more coherent regulatory framework. Drawing on the 1964 Venice Charter[20], it defined historic centres as "*urban settlement structures that constitute a cultural*

14 ANCSA – Associazione Nazionale Centri Storico Artistici 1960. The Gubbio Charter was published in 1960 as a direct result of the National Conference for the Protection and Recovery of Historic Centres (Gubbio, 17-18-19 September 1960) by a group of architects, urban planners, jurists, restoration scholars, and the representatives of eight Italian Municipalities. In 1961 the National Association of Historic and Artistic Town Centres (ANCSA 2021) was formed to provide an institutional platform for disseminating and consolidating this new vision of historic urban conservation.

15 ANCSA 1960. In Italian, these peculiar DPs are referred to as *Piani di Recupero*.

16 The Superintendencies for Archaeology, Fine Arts, and Landscape aare heritage protection bodies established in the early twentieth century. Today, they operate under the jurisdiction of the Ministry of Culture and are responsible for overseeing the safeguarding, conservation, and management of cultural assets across the national territory.

17 D'Alessio 1983; Marzocca 2007.

18 Following the Bottai Laws, the Superintendencies acquired broader authority, extending their jurisdiction to include the environmental context surrounding cultural assets. However, their role continued to be affected by the fragmented definition of the historic centre.

19 Italian Government 1964.

20 The Charter of Venice for the Restoration and Conservation of Monuments and Sites (Gazzola *et al.* 1964, article 1) states that a '*historic monument includes not only the single architectural work but also the urban or rural setting which is the evidence of a particular civilization, a significant development, or a historic event. This concept applies not only to major works but also to more modest works which have acquired cultural significance over time*'.

*unit or the original and authentic part of settlements, bearing witness to a vibrant urban culture*"[21], and included them within cultural heritage understood as "*material evidence of civilisation*"[22]. At least at the level of principle, this definition moved beyond a strictly aesthetic conception and extended conservation aims to the preservation of the historic centre's vitality. The Commission also recommended safeguarding historic urban environments through the regulatory provisions of GDPs, with a supervisory role for Superintendencies during the drafting process led by municipalities[23].

However, the implementation of the 1942 framework remained limited and, by 1967, only a small number of municipalities had adopted a GDP. In response to widespread irregularities and the slow progress of plan-making, the Ministry of Public Works introduced a set of interim measures[24]. The 1967 "Bridge Law" made provisions for safeguarding historic built environments within the GDP mandatory, signalling a shift towards treating historic fabrics as a planning issue rather than a residual preservation concern[25].

This orientation was reinforced by Ministerial Decree No. 1444/1968, which introduced Homogeneous Territorial Zones and, among them, Zone A, defined as "*those parts of the territory affected by urban agglomerations of historical, artistic, or particular environmental value, or portions thereof, including surrounding areas that, due to such characteristics, may be considered integral parts of the agglomerations themselves*"[26]. This category established the main planning perimeter for historic centres within the zoning system. Within Zone A, new construction and alterations were constrained through limits on height and spatial relationships, aiming to maintain continuity with pre-existing urban form[27]. Through these provisions, historic centres entered the planning system as a specific category to be regulated, alongside urban expansion and infrastructure development.

At the same time, the zoning approach relied on fixed perimeter demarcations that struggled to reflect the layered character of historic urban landscapes. Moreover, these instruments were primarily oriented towards controlling growth and standardising parameters, rather than providing a fully articulated framework for interventions within historic cores[28]. Furthermore, DPs affecting assets protected under the 1939 Bottai Laws were required to be submitted either to the competent Superintendency or to the Ministry of Public Education, depending on the approving authority, reinforcing the

21 Commissione Franceschini 1967, volume I, declaration XL.

22 Commissione Franceschini 1967, volume I, declaration I.

23 *Ivi*, declaration XL and declaration XLVI.

24 Scattoni, Falco 2011, pp. 21-22.

25 Italian Government 1967. The Act is known as Bridge Law as it was thought to be a "bridge" between the Fundamental Planning Law and the expected new reform.

26 Italian Government 1968, article 2.

27 *Ivi*, art. 5.

28 Atzeni *et al.* 2022, p. 2.





hybrid nature of competences between planning and heritage administration[29]. Although these measures introduced significant constraints and definitions, they did not substantially accelerate the drafting of GDPs. A more structural turning point occurred in the second half of the 1970s, when key planning competences shifted from the Ministry of Public Works to the Regions[30]. The volume and heterogeneity of plans, together with the differentiated needs of the Italian territory, made the centralised model increasingly unsustainable. In the subsequent decentralisation framework, Regions acquired broad responsibilities in planning, construction, landscape regulation, and environmental conservation, and many delegated selected powers to municipalities or inter-municipal entities, including responsibilities related to GDP preparation and implementation[31].

Despite decades of experience in urban management and sustained efforts to protect historic urban fabrics, the Italian planning system continued to struggle to reconcile conservation objectives with processes of urban development[32]. Within this context of unresolved tensions, a gradual shift in perspective began to take shape. Following the widespread building expansion that transformed many Italian cities throughout the 1960s, the notion of the historic centre as a dynamic urban space, reaffirmed and expanded in the 1972 Conservation Charter[33], gained increasing traction within planning discourse. Partly through the awareness-raising initiatives promoted by ANCSA, historic centres came to be recognised not only as heritage assets to be safeguarded but also as shared urban resources. This recognition supported a growing orientation towards the reuse of existing urban fabric, especially as the limits of expansion-led growth became more widely debated[34].

Within this framework, a range of initiatives emerged to address degraded or underused areas, including Recovery Plans and other forms of DPs aimed at improving housing conditions and urban services while taking account of the

29 Roccella 2005, p. 6. Submission channels varied according to whether the DP was approved at regional level or by the Ministry of Public Works, reflecting the overlap between planning approval procedures and statutory heritage protection.

30 Italian Government 1975; Italian Government 1977.

31 Scattoni, Falco 2011, pp. 24-25.

32 Carozzi, Mioni 1970, pp. 430-431.

33 Conservation Charter 1972, attachment D; Pane 1971, pp. 13-15. The Charter defined the historic centre as a "*document of urban culture*" whose significance goes beyond aesthetics. It described historic centres as human settlements, cohesive or fragmented, that possess historical, urban, or architectural value, even if altered over time. This formulation echoes Roberto Pane's distinction between the "ancient centre" as the original nucleus and the "historic centre" as the stratified fabric shaped by successive expansions. Consequently, the historic centre came to be understood as a layered palimpsest, deserving protection regardless of artistic or formal qualities, with conservation to be preceded by rigorous knowledge of its historical and cultural values.

34 ANCSA n.d.

historic and architectural significance of the built environment[35]. However, construction activity often continued in ways that exceeded effective control, and was at times accelerated by exceptional circumstances, including major events and post-disaster reconstruction processes[36].
At the same time, the evolving understanding of the historic centre as a living environment remained in tension with approaches that treated conservation primarily as the preservation of form and material integrity. Where regulatory and administrative practices were interpreted rigidly, limited flexibility and the marginalisation of social dynamics could hinder compatible adaptation to contemporary liveability needs, with outcomes that included abandonment, selective gentrification dynamics, and the persistence of unauthorised interventions[37]. In the 1980s, this situation was further complicated by legislative measures that regularised non-compliant construction through amnesties, weakening the deterrent effect of planning enforcement and reinforcing informal practices[38]. These issues were discussed by ANCSA in the Second Gubbio Charter (1990)[39], which linked them to the broader urban crisis experienced across Europe and called on local authorities to investigate the dynamics underlying these phenomena and to develop planning methodologies capable of responding to them. This agenda implied acknowledging historic centres as complex and evolving realities not only in theory, but also through approaches that engage territorial context and integrate socio-economic and environmental dimensions[40].
A related orientation informs the 1992 Charter of City Rights[41], which frames urban complexity as a component of cultural richness and recognisability that evolves over time. Within this view, historic centres cannot be treated as static entities, but require active reuse and functional transformation beyond purely museal interpretations[42]. From the early 1990s onward, this orientation contributed to the development of a category of planning instruments known as Complex Programmes. Throughout the 1990s and into the early 2000s, these programmes progressively expanded their scope beyond physical degradation to include socio-economic, cultural, and identity-related

35 Italian Government 1978; Colavitti, Serra 2017, p. 80.

36 ANCSA n.d.

37 Italian Government 1978; Colavitti, Serra 2017, pp. 80-81.

38 e.g. Italian Government 1985a, the "building *condono*".

39 ANCSA 1990, outcome of the Gubbio Conference 'Issues of Local and Territorial Authorities' (Gubbio, 1990).

40 *Ibidem*.

41 Ceccarelli *et al.* 1992.

42 *Ibidem*.





dimensions[43]. Nevertheless, their outcomes were often uneven. Among the reasons frequently highlighted is the mismatch between the responsibilities assigned to municipalities and the limited transfer of resources, competences, and institutional capacity from central and regional levels[44]. A series of reforms culminated in a stronger concentration of plan-making and planning control at municipal level, accompanied by diminishing external oversight[45]. In this context, peripheral state offices such as the Superintendencies saw their influence in planning processes reduced, remaining primarily focused on binding opinions for statutorily protected properties and areas[46].
Taken together, these developments reveal a recurrent pattern in the Italian framework for historic centres: advances in definitions and principles have not always been matched by equally robust implementation capacity. Zoning categories, procedural controls, and heritage oversight contributed to establishing safeguards, yet operational guidance often remained partial, fragmented across institutions, and unevenly applied, particularly where municipal technical capacity was limited and responsibilities expanded faster than resources and coordination mechanisms.

43 Complex Programs [*Programmi Complessi*] (Italian Government 1992) were subsequently integrated with the Urban Recovery Programs [*Programmi di Recupero Urbano* – PRU] (Italian Government 1993, ex article 11); the Neighborhood Contracts [*Contratti di Quartiere* – CdQ] (Italian Government 1997b; Italian Government 1998a; Italian Government 2001b); and the Urban Redevelopment and Sustainable Territorial Development Programs [*Programmi di Riqualificazione Urbana e di Sviluppo Sostenibile del Territorio – PRUSST*] (Italian Government 1998b).

44 Clementi 2002.

45 Italian Government 1997a.

46 Scattoni, Falco 2011, pp. 23-24.

### 1.1.2 Landscape as Cultural Identity: the 21st-Century Shift in Italian Policy and Planning

At the European scale, the notion of landscape progressively expanded from a primarily scenic and exceptional object to a broader understanding that includes cultural landscapes. This shift was formalised with UNESCO's recognition of "cultural landscapes" (1992)[47] and consolidated by the European Landscape Convention (2000)[48], which defines landscape as "*a specific portion of territory, as perceived by populations, whose character results from the interaction of natural and human factors*"[49]. This broader vision significantly influenced the Italian framework, where landscape increasingly became a key interpretive category for territorial identity rather than a residual layer of constraints.

In Italy, the Code of Cultural Heritage and Landscape or Urbani Code (2004), particularly as amended in 2008[50], incorporates the notion of landscape as an expression of identity emerging from the historical interaction of natural and cultural components[51]. It includes within landscape heritage "*groups of immovable properties that form a characteristic aspect of aesthetic and traditional value, such as historic centres and nuclei*"[52]. The main innovation lies in treating territory as landscape, moving beyond earlier approaches that framed protection as an exceptional regime based mainly on restrictive measures[53]. The European Landscape Convention also links this shift to a public responsibility, calling for safeguarding, management, and planning measures, and for the active involvement of populations and institutions in recognising and shaping landscape values[54]. At the same time, this paradigm introduces a structural tension between expanded recognition and operational governability. Broadening what counts as landscape heritage multiplies the range of situations requiring interpretation, negotiation, and judgement. Without corresponding tools, shared criteria, and institutional capacity, the landscape paradigm may oscillate between two imperfect outcomes: either an abstract declaration of value that remains difficult to translate into design guidance, or a compliance-oriented reading that reduces landscape to a checklist of constraints.

Within this framework, Regional Landscape Plans (RLPs), made mandatory

47 UNESCO 1992.

48 Council of Europe 2000.

49 *Ivi*, chapter 1, article 1, letter a.

50 Italian Government 2008a.

51 Italian Government 2004, third part, title I, chapter I, article 131.

52 *Ivi*, article 136, letter C, modified by Italian Government 2008.

53 e.g. Italian Government 1939b.

54 Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Milano 2021.





by the Galasso Law (1985)[55], are tasked with identifying areas of public interest and defining guidelines for territorial and architectural development consistent with protection objectives[56]. Drafted through co-planning with the State, and in particular with the Ministry of Culture (MiC), RLPs are intended to align protection goals with planning choices, including rehabilitation and enhancement strategies. In contrast to traditional urban planning, the RLPs represent a significant shift toward integrating urban development with the rehabilitation of existing environments[57]. In practice, however, their effectiveness depends on how clearly prescriptions are specified, how consistently they are implemented across municipalities, and whether they are supported by adequate technical capacity.

A further implementation gap can emerge at the interface between landscape planning and ordinary municipal planning. Where the connection between RLP prescriptions and local plan provisions is weak, landscape objectives risk remaining generic or being translated unevenly across territories. This is particularly relevant for historic centres and minor settlements, where change often occurs through incremental interventions rather than through major projects. In such contexts, the cumulative effect of small-scale works may gradually alter landscape coherence if not framed by consistent operational guidance[58].

The Code also regulates interventions in protected areas through the mechanism of landscape authorisation. Owners of protected properties or areas are prohibited from actions that may compromise recognised landscape values, and projects affecting protected areas must be assessed for landscape compatibility[59]. Procedures are generally managed by municipalities under regional delegation, supported by local commissions for architectural quality and landscape, and ultimately subject to the mandatory and binding opinion of the Superintendence[60]. While this system strengthens formal control, it may also encourage a compliance-driven approach, particularly where planning frameworks are weak or fragmented. In those cases, the assessment can become concentrated on procedural correctness and formal conformity, rather than on the longer-term coherence of transformations with the landscape objectives set out by the plan.

The simplified landscape authorisation introduced in 2017 applies to minor interventions through an accelerated procedure, distinguishing works excluded from authorisation and works subject to simplified assessment[61].

55 Italian Government 1985b.

56 Colavitti, Serra 2017, p. 81; Sau 2018, p. 10.

57 Colavitti, Serra 2017, pp. 80-81.

58 MiBACT 2018a, pp. 37-38; Atzeni et al. 2022, pp. 5-6.

59 Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Milano 2021.

60 Italian Government 2004, third part, title I, chapter IV, articles 146 and 148.

61 Italian Government 2017b.

Debates emerging from the General States of the Landscape[62] highlighted the ambiguity of this shift. On the one hand, simplification can reduce procedural burdens and allow Superintendencies to focus on priorities[63]. On the other, without a parallel strengthening of institutional structures and shared rules, shorter deadlines and the exclusion of certain works from full assessment may marginalise oversight and increase the risk of cumulative impacts on landscape quality[64].

In response, the National Landscape Charter (2018)[65] reaffirmed landscape as a common good and a foundation for public policy, not limited to protection[66]. It called for stronger institutional structures, the centrality of the landscape plan, and an integrated approach linking conservation, enhancement, and sustainable development[67]. In this perspective, Superintendencies are not merely procedural actors, but part of a wider strategy aimed at building a shared landscape culture capable of guiding future transformations in terms of quality, legality, and social cohesion[68].

Taken together, this evolution shows a clear shift from protection conceived as an exceptional and mainly restrictive regime towards a landscape paradigm grounded in identity, public responsibility, and negotiated governance. Yet without consistent tools, shared criteria, and adequate institutional capacity, objectives can remain generic. In this sense, the role of public authorities and Superintendencies becomes pivotal, not only as control bodies but as actors that enable workable guidance and continuity between plans, authorisations, and everyday transformations. Figure 1 summarises this trajectory by mapping the main legislative steps, planning instruments, policy documents, and guidelines that have shaped the protection of historic centres and landscapes in Italy, together with the changing responsibilities assigned to Superintendencies and other public administrations.

62 The General States of the Landscape are an Italian initiative launched by the former Ministry of Cultural Heritage and Tourism (MiBACT), aimed at taking stock and promoting a national reflection on the state of landscape policies, specifically in terms of protection, enhancement, and transformation. The initiative resulted in an informational report that provides a comprehensive snapshot of the actual condition of landscape policies (Ministero dei beni e delle attività culturali e del turismo – MiBACT 2018a).

63 MiBACT 2018a, p. 97.

64 *Ivi*, pp. 37-38, 98-99.

65 MiBACT 2018b.

66 *Ivi*, p. 6.

67 *Ivi*, pp. 11-12.

68 *Ivi*, pp. 3,5.





| Period and Document of Reference | Law/ Document | Proposed Planning Tools | Role of Superintendecies | Role of Public Authorities |
|---|---|---|---|---|
| **1939 Bottai Laws** | Law no longer in force | | Limited to isolated monuments | |
| **1942 Fundamental Planning Law** | Law in force | TCPs, GDPs, DPs | Intervention limited to buildings protected under the 1939 heritage laws | Ministry of Public Works: drafting TCPs and approving GDPs; Provinces: approving GDPs for minor centres; Municipalities: drafting and implementing GDPs |
| **1960 Gubbio Charter** | Document, Conference Proceedings | Proposed: GDPs for the protection of historic urban environments; Conservative Recovery Plans (DPs) | | |
| **1964 Franceschini Commission** | Document, Report | Proposed: GDPs for the protection of historic urban environments | Proposed: Supervising the drafting of GDPs, without binding powers | |
| **1967-68 Brige Law and M.D. No. 1444** | Law in force with amendments | GDPs (mandatory) and Zoning according to Homogeneous Territorial Zones | Opinion issued on DPs involving protected assets approved by the regional authority | Ministry of Public Education: opinion issued on DPs involving protected assets approved by the Ministry of Public Works |

| Period and Document of Reference | Law/ Document | Proposed Planning Tools | Role of Superintendecies | Role of Public Authorities |
|---|---|---|---|---|
| **1970s-1990s Progressive Delegation of Planning competence to Regions and Municipalities** | Some in force with amendment, some no longer in force | | Issuing binding opinions on properties or areas subject to statutory protection | Region: drafting and approving TCPs Municipalities: drafting and implementing GDPs and DPs; approval progressively shifted from the Regions to the Municipalities through reforms in the 1990s |
| **2004 Urbani Code** | Law in force | RLPs (mandatory) | Issuing binding opinions on landscape compatibility of interventions in areas of landscape interest; inquiry for the imposition of constraints on landscape assets; annulment powers for authorizations issued in breach of the law | Regions and MiC: co-planning for the drafting of RLPs; Regions: issuance of landscape authorisation; Municipalities: drafting, approving and implementing GDPs; drafting, approving and implementing DPs according to RLPs regulations |

**Fig. 1**
*Overview table of the evolution of Italian legislation, planning tools documents, and guidelines for the protection of historic centres and landscapes, and the changing roles of Superintendencies and public authorities. Source: author's elaboration.*





## 1.2 The Issue of Small Historic Villages and Inner Areas in the 21st Century

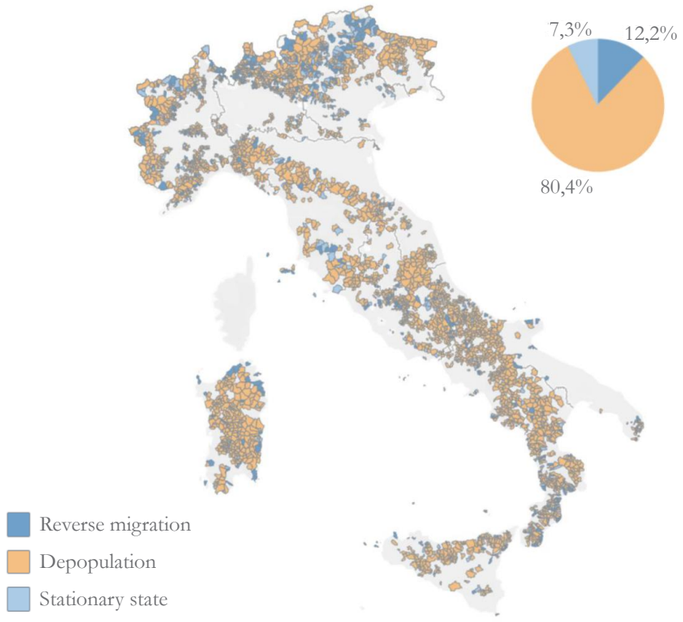
In Italy, following the Code of Cultural Heritage and Landscape and in parallel with the formulation of Regional Landscape Plans, growing emphasis was placed on the need to undertake a deeper analysis of historic centres[69]. This was particularly urgent in light of processes markedly distinct from those of the previous century, such as the acceleration of urbanisation and the emergence of new socio-spatial dynamics. As Ferlenga observes,

"*too many new phenomena have affected them—from emigration that strips them bare to new immigration that occupies them, from degradation that destroys them to the explosion of tourism that suffocates them—for us to still claim they are the same*"[70].

Against this background, a brief European frame is used only as a point of comparison, situating the Italian case within wider early 21st-century debates on territorial cohesion and spatial inequality, particularly in relation to peripheral and sparsely populated areas where access to services, demographic trends, and environmental pressures intersect.
This perspective helps clarify that the challenges affecting major heritage cities and those shaping small towns and villages are often structurally different, even if they may coexist within the same regional system. In Italy, large cities with significant cultural and artistic heritage have received particular attention due to their attractiveness, while the challenges faced by villages and smaller historic centres are often "*overshadowed by the opposite phenomenon*"[71]. In heritage-rich cities, market dynamics can prevail over cultural and social values, leading to gentrification and touristification that threaten urban heritage, exacerbate housing pressures, and generate social tensions[72]. Conversely, many small settlements, rather than dealing with excess, are marked by marginalisation, demographic decline, and limited access to services and opportunities, which threaten their long-term viability and cultural continuity[73].
In this chapter, "inner areas" are therefore considered as a policy-relevant category that links spatial marginality with accessibility and service provision, while small historic villages (*borghi*) are read as a specific component of that geography, where heritage conservation, territorial cohesion, and environmental adaptation increasingly intersect. To understand why this category becomes so structurally significant in Italy, it is necessary to trace the long-term formation of territorial disparities and the historical processes that progressively concentrated population, services, and opportunities in a limited number of urban poles.

69 Giambruno 2007; Fiorani 2019; Sanzaro 2022.
70 Ferlenga 2017, p. 16.
71 Nigrelli 2021, p. 35.
72 Ferro *et al.* 2024.
73 Barca et al. 2014, p. 7.

**Fig. 2**
*Italian municipalities with less than 5000 inhabitants. Source: ANCI 2019.*




### 1.2.1 Historical Marginalisation and Emerging Cultural Values of Italian Inner Areas

Italy's relatively recent unification in 1861 brought together regions characterised by markedly different socio-economic structures, consolidating enduring territorial disparities. These have long ranged from the North-South divide to more localised imbalances between larger urban centres and smaller settlements[74]. Unlike the more gradual transitions of other European countries, in the space of a century, Italy's population doubled, from 25 million in 1861 to nearly 50 million by 1961, with growth concentrated in urban areas, prompted by the establishment of industrial poles. The uneven pace of industrialisation compared to agriculture, together with the development of communication networks, led to the marked growth of municipalities that already had substantial populations at the time of unification, a proliferation in the number and relevance of medium-sized towns, and a gradual decline in the functional capacity of smaller centres[75] (Fig. 2).
Such conditions not only shaped Italy's initial urban configuration but continue to influence the relationship between urban and rural areas[76].
In contemporary policy and planning discourse, these marginalised

74 Carozzi, Mioni 1970, pp. 21-26.
75 Mortara 1970, pp. 78-79.
76 Carozzi, Mioni 1970, pp. 21-26.





**Fig. 3**
*Reasons for abandonment of rural settlements. Source: Güler, Kâhya 2019, p. 98.*

| A. Human-based reasons | | | B. Nature-based reasons |
|---|---|---|---|
| A. 1. Socio-cultural and economic reasons | A. 2. Politic Reasons/ Conflicts | A. 3. Other reasons | |
| Economic decline/ The lack of rural finance / Inadequate rural policies | War and conflicts between countries | Expropriations due to Construction of Public Works or Urban Development Activities | Natural constraints |
| The overall economic context of countries/ Territorial inequalities | Civil war | | Climate change/ Global warming |
| Unemployment/Agricultural inefficiency/ The fall of agricultural holdings/ Ageing population/ Migration | Terrorism, Security Vulnerabilities | Location on an Archaeological Site (Multi-layered Settlements) | Earthquakes |
| Lack of public investments and services/ Remoteness from focal points | Mandatory Migrations/ Evacuations | Location on a high valued mine reserve | Fires |
| Difficulty in Access to Education, Health, Culture, Services, etc. | Political Discrimination/ Oppression Policies | | Floods |
| Lack of infrastructure, transportation and communication | Racism | Exhaustion of mine reserves | Avalanches |
| Dissatisfaction with living conditions/ Search for a better life | Legal obstacles | | Landslides/ Erosion |
| Negative social image of rural/ Desire for big city lifestyle/ Desire for upward mobility/ Concerns relating to land ownership and distribution | | Pollution and Environmental degradation | Volcanic disasters |

territories are commonly referred to as inner areas. The term does not simply describe "rurality", but a condition of relative distance from service hubs for education, healthcare, and mobility, where accessibility constraints interact with demographic decline and ageing[77]. As a policy category, "inner areas" is useful to map structural disadvantages and to prioritise resources; however, it can also mask strong internal heterogeneity and very different local trajectories if the label is applied too uniformly[78].
The drivers of depopulation and abandonment are multidimensional and interdependent, combining long-term structural dynamics with site-specific triggers. Studies have variously summarised these factors, including distinctions between human-induced and nature-based causes[79] (Fig. 3).
At the same time, it is important to avoid reading abandonment as a purely contemporary anomaly. Throughout history and across various regions, territories have experienced recurring cycles of growth and decline, as part of natural processes or triggered by disruptive events and intentional political decisions[80]. As an example, in Sardinia, a particularly significant wave of territorial reorganisation took place between the 14th and 15th centuries,

77 Barca et al. 2014, p. 7.
78 Ietri, Pagetti 2019.
79 Güler, Kâhya 2019, p. 98.
80 Scamardì 2020, p. 20.

leading to the disappearance of nearly 450 villages[81]. What is distinctive today is not the existence of decline per se, but the way it intersects with service withdrawal, demographic ageing, and the weakening of ordinary maintenance cycles in already fragile settlement systems.
In parallel, the cultural meaning attributed to these territories has also evolved. Inner areas are increasingly framed as repositories of environmental resources, cultural landscapes, and long-term knowledge embedded in practices of inhabiting and land management. Even where socio-economic indicators are weak, many of these places retain legible material and spatial evidence of historical relationships between settlement form, production systems, and landscape transformation. In regional contexts such as Sardinia, the connection between small settlements and geographical, topographical, and climatic conditions often remains recognisable, supporting the reading of villages as "*the nodes of a wider network that supports the weave of the historical territory*"[82]. They embody the distinctive characteristics of their territory, its economy, traditions, dialects, agriculture, gastronomy, and culture, forming a "*kaleidoscope of landscapes*"[83].

"*Rural areas that are less easily accessible, historically characterised by a limited provision of such services, have undergone a long and gradual process of abandonment in favour of urban areas, resulting in high societal costs such as hydrogeological instability, environmental degradation, and land consumption.* [...] *These same territories, however, also hold significant unused territorial, natural, and human capital, considered strategic for the revitalisation and development of the Italian national system*"[84].

This shift has supported renewed interest in historic villages not only as "picturesque" artefacts, but as embodying ways of life that offer meaningful alternatives to some adverse effects of contemporary urbanisation, where tangible fabric and intangible competences co-produce identity and continuity[85]. The identity of historic villages stems from the interaction between natural resources and human activity, shaping distinctive Historic Urban Landscapes[86] that situate the settlement within a broader territorial framework. This perspective highlights a layered assemblage of historical, cultural, and environmental values that extend beyond the traditional boundaries of the 'historic centre', encompassing both tangible and intangible dimensions[87].
At the same time, this revaluation can be ambivalent. Narratives of authenticity and "heritage-led revival" may generate new attention and resources, yet

81 *Ivi*, pp. 29-31.
82 Sanna 2009a, p. 11.
83 Cerosimo, Donzelli 2020, p. 7; Oteri 2020, p. 47.
84 Barca *et al.* 2014, p. 3.
85 Kealy 2020, pp. 101-103.
86 UNESCO 2011.
87 Atzeni *et al.* 2022, p. 3.





they can also become selective and externally driven, privileging image and consumption over long-term habitability, local agency, and everyday maintenance. In other words, the recognition of value does not automatically translate into the conditions that allow villages to remain inhabited systems, nor into operational guidance capable of steering compatible transformations.
Despite the consolidation of landscape and heritage protection frameworks such as the Urbani Code, large portions of Italy's inland territories have continued to experience marginalisation, with consequences that extend beyond population loss. Socio-economically, this includes shrinking employment opportunities, reduced availability of services and infrastructures, and the fragmentation of communities and sense of place. Culturally, it can involve the abandonment of building stock, the gradual erosion of traditional know-how linked to vernacular construction, and interventions on historic fabrics that are incompatible with materials and spatial logics. Environmentally, weakened maintenance can increase hydrogeological instability and contribute to landscape degradation[88].
In some cases, additional pressures have followed from interventions oriented primarily towards resource extraction or sectoral objectives, with limited benefits for local communities, including quarrying, inadequate forest management, and, in certain contexts, energy production facilities[89]. Moreover, local administrations are often encouraged to redirect attention towards more recent settlement expansions and "proximate peripheries", which may concentrate social vulnerability while historic cores continue to lose functions and residents[90]. Over the past decades, regeneration agendas have therefore frequently privileged newer urban fragments, sometimes at the expense of sustained critical engagement with historic heritage and of long-term policies for its compatible management and reuse[91].

### 1.2.2 A Comparative European Frame for Inner Areas and Small Settlements

Inner areas are not a uniquely Italian phenomenon. In European debates they are often discussed under the notion of inner peripheries, which emphasises not only geographic remoteness but also differentiated levels of "connectedness", understood in institutional, relational, and infrastructural terms[92]. This framing helps interpret peripheral conditions as the result of uneven access to networks, services, and decision-making capacity, rather than as a purely spatial fact (see Figs. 4 and 5).

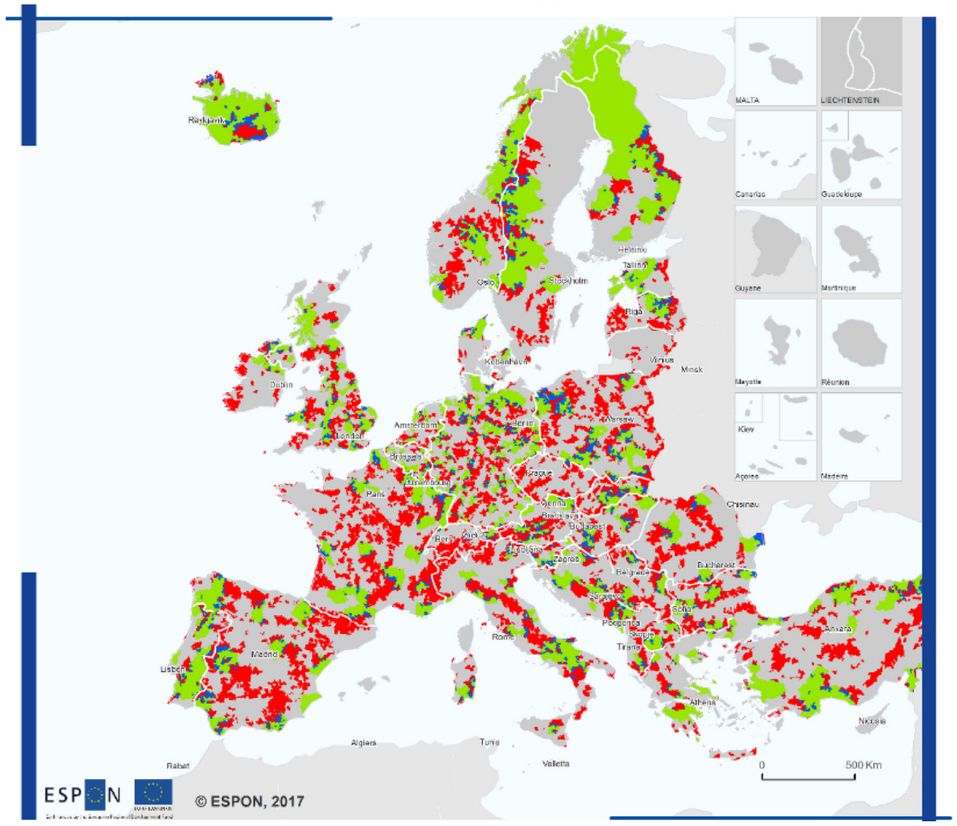
88 Amodio 2021, p. 51.
89 Barca *et al.* 2014, p. 7.
90 Amendola 2019, p. 12.
91 Storchi, Oberdan 2010.
92 ESPON 2018, pp. 2-3.

In recent policy guidance, at the international level, responses to demographic decline in peripheral areas are often described along a spectrum: from strategies that mainly try to counteract shrinkage through compensatory measures, to approaches that accept continuing decline and focus on adapting services, infrastructures, and governance to maintain quality of life. This latter orientation, sometimes discussed as "managing" or "coping with" shrinkage, reframes contraction as a condition to be governed rather than reversed[93].

At EU level, rural and territorial cohesion objectives are supported by a set of funding channels and delivery mechanisms aimed at reducing socio-economic disparities, countering depopulation, and strengthening local

93 Oswalt 2006; Hospers e Reverda 2015, p. 69; ESPON 2017, p. 2; Monardo 2023, p. 60.

**Fig. 4**
*The four delineations of Inner Peripherality (IP) in Europe according to the main driver. Source: ESPON 2017, p. 2.*




**Overlay of results of the four individual delineations: Main drivers of inner peripherality (lack of access vs. economic and demographic situation)**

- non-IP area
- Main driver: poor economic potentials and poor socio-economic situation
- Main driver: lack of access to centres and/or services
- Main driver: poor accessibility and poor economic potentials/poor socio-economic situation





services[94]. Alongside mainstream instruments, bottom-up approaches such as LEADER, implemented through Community-Led Local Development (CLLD), have been promoted to support place-based strategies defined by Local Action Groups[95]. More recent initiatives, including the Rural Pact[96] and the Rural Toolkit[97], seek to improve coordination across policy levels and to facilitate access to instruments and guidance for local administrations.

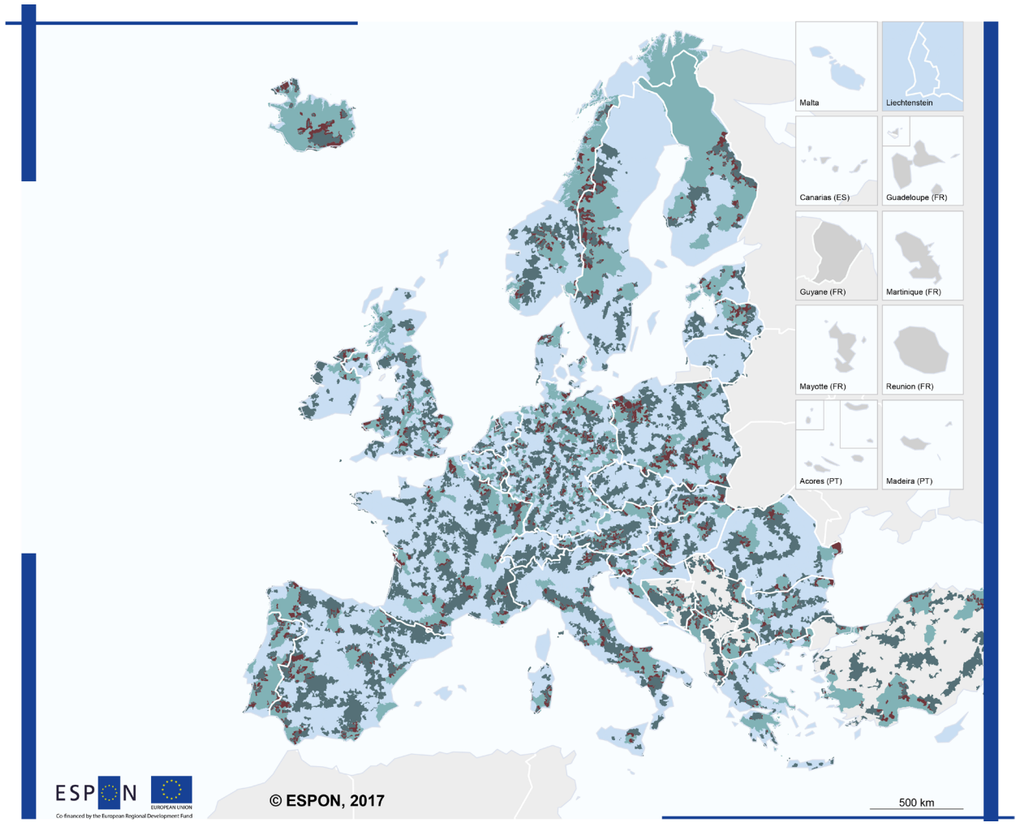
94 For example the European Agricultural Fund for Rural Development (EAFRD, European Commission n.d.a) or the European Social Fund Plus (ESF+, European Commission n.d.b)

95 European Network for Rural Development 2021.

96 European Union n.d.a

97 European Union n.d.b

**Fig. 5**
*The Main drivers of inner peripherality (IP) in Europe. Source: ESPON 2018, p. 4.*




**Main socio-economic drivers of inner peripherality**

- poor socio-economic situation and economic potential
- lack of access to regional centres and/or services
- poor accessibility, socio-economic situation and economic potential

While these frameworks provide important opportunities, they also highlight a recurrent issue: outcomes depend heavily on local capacity to organise knowledge, build coalitions, and translate funding into coherent long-term strategies.

Several national governments have complemented EU measures with targeted programmes for marginal territories, often focusing on urban–rural partnerships and territorial solidarity. In France, for instance, *Contrats de réciprocité* have been developed as voluntary agreements between metropolitan or medium-sized cities and surrounding rural areas, aiming to coordinate services, economic development, environmental management, and heritage valorisation[98]. This orientation resonates with principles articulated in the Leipzig Charter (2007), which stressed the need for integrated strategies that connect metropolitan centres with smaller settlements rather than treating them as separate policy worlds[99].

Within this comparative frame, the Irish case is introduced as a focused example because it makes particularly visible the implementation gap between policy ambition, institutional capacity, and operational tools. Despite an overall positive demographic trend[100], more remote rural areas and smaller settlements continue to face persistent decline[101]. Small towns and villages, commonly defined up to 5,000 inhabitants, represent a large share of the settlement network, as shown in Fig. 6, and their vulnerability has implications for services, local economies, and the condition of town centres[102]. Challenges include youth outmigration, limited infrastructure, increasing vacancy and dereliction, and the erosion of everyday vitality in central areas[103]. This vulnerability has also been shaped by institutional reorganisation, including the 2014 local government reform that abolished many Town Councils and reconfigured sub-county governance, with debated effects on local representation and delivery capacity[104].

Policy responses in Ireland have increasingly framed town centres as strategic assets. Reports such as The Town Centre Living Initiative pointed to weak coordination at national level, fragmented funding streams, and gaps in accessible, high-quality data on town centres, while also emphasising the opportunity to reimagine towns as inclusive and liveable places[105]. Building

98 Battisti 2020, p. 82; ANPP 2022.

99 European Union 2007.

100 CSO 2022. Demographic trends between 1996 and 2016 indicate substantial growth, with cities and suburbs expanding by 23% and smaller towns by 62%, particularly in 'commuting towns' near major urban centres. More recent trends, confirmed by the 2022 population census, indicate that Ireland's overall population increased by about 8%, with growth concentrated in cities, suburbs, and larger towns.

101 World Bank Group 2024.

102 Government of Ireland 2023a, p. 10.

103 Government of Ireland 2018, p. 8.

104 Jordan, Wright 2023, pp. 395-396.

105 Space Engagers 2020, pp. 12-13.





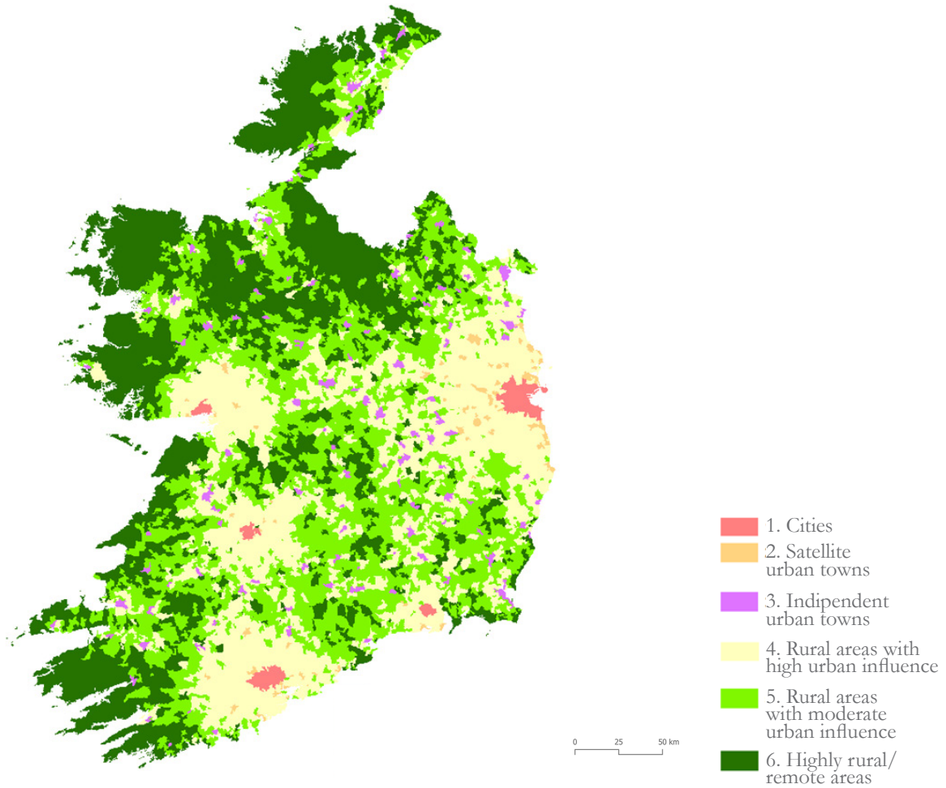



**Fig. 6 (above)**
*The classification of urban/ rural areas using 2016 census results. A significant portion of the area is characterised by a dense scattering of small villages, particularly across rural and central regions.*
*Source: CSO 2019.*




**Fig. 7 (below)**
*Roles and Key Responsibilities within the Town Centre First Policy.*
*Source: Government of Ireland 2023a, p. 30.*

on this agenda, Our Rural Future 2021–2025 and the Town Centre First approach promote a place-based model in which town centres are treated as multifunctional hubs for living, working, and social life, explicitly linking regeneration to heritage, identity, and long-term sustainability[106]. Importantly, the Irish framework also stresses delivery structures within Local Authorities and the mobilisation of local actors, including the establishment of Town Teams that bring together residents, businesses, and stakeholders as "local experts", in a multilevel structure as shown in Fig. 7[107].
Overall, the European comparison does not serve here as a comprehensive overview, but as a way to clarify a point that is directly relevant to the Italian debate: beyond funding availability or policy rhetoric, effective action in inner and marginal areas depends on operational frameworks that connect knowledge, governance capacity, and implementable tools. This theme is especially pertinent for small historic settlements, where change often occurs through incremental transformations and where the alignment between heritage values, local administration, and concrete project guidance becomes decisive.

### 1.2.3 Italian Territorial Cohesion Policies for Inner Areas and Small Settlements

In Italy, the first structured territorial cohesion policy explicitly targeting marginalised territories was the National Strategy for Inner Areas (SNAI), launched experimentally in 2014 within the Partnership Agreement for European Cohesion Policy 2014 to 2020 and later consolidated for the 2021 to 2027 cycle[108]. The SNAI targets inner areas, defined as territories that are significantly distant from hubs providing essential services (education, healthcare, and mobility), yet endowed with important environmental and cultural resources and shaped by long-term settlement processes[109].
Under the 2021 to 2027 Partnership Agreement, the configuration of inner areas was updated, while support was maintained for territories already identified in the previous cycle, irrespective of any subsequent reclassification[110]. Figure 8 shows the updated delineation of inner areas and the proximity-based categories (in relation to essential-service hubs) used to classify Italian territories. Figure 9 complements this spatial classification by summarising the condition of inner areas as a balance between underused

106 Government of Ireland 2021.

107 Government of Ireland 2023a.

108 The SNAI was originally incorporated into the 2014 National Reform Programme (PNR), which outlined the measures to be implemented that year in pursuit of the national targets set by the Europe 2020 Strategy.

109 Barca *et al.* 2014, p. 7.

110 Dipartimento per le politiche di coesione e per il sud 2022, p. 7.





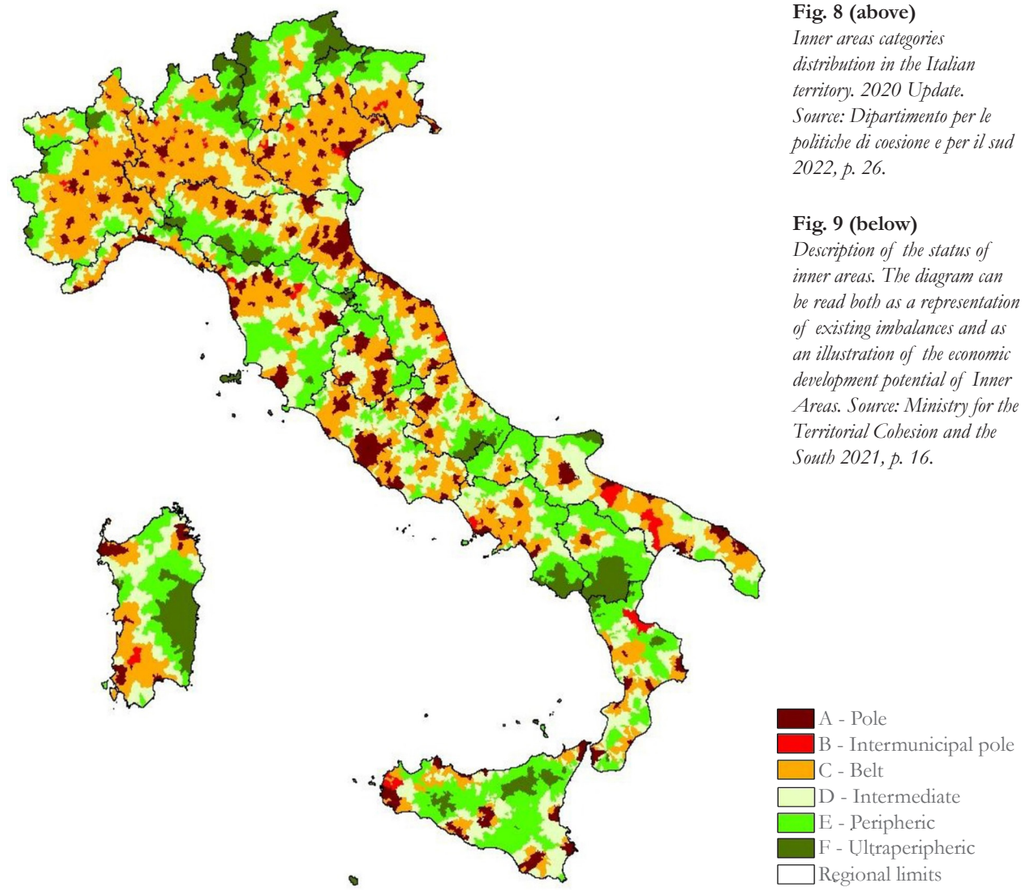
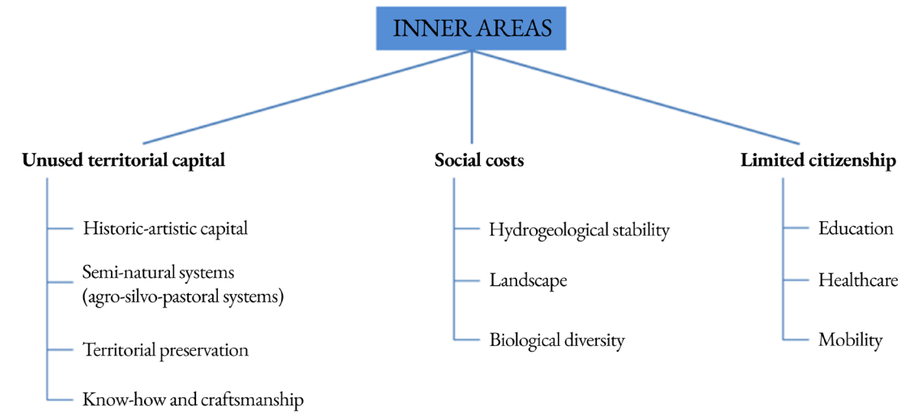



**Fig. 8 (above)**
*Inner areas categories distribution in the Italian territory. 2020 Update. Source: Dipartimento per le politiche di coesione e per il sud 2022, p. 26.*

**Fig. 9 (below)**
*Description of the status of inner areas. The diagram can be read both as a representation of existing imbalances and as an illustration of the economic development potential of Inner Areas. Source: Ministry for the Territorial Cohesion and the South 2021, p. 16.*



territorial capital, social costs, and limited citizenship, framing these contrasts both as existing imbalances and as potential development levers. This framing matters because it suggests that feasibility depends not only on design choices, but also on administrative capacity and access to essential services, which condition implementation and long-term maintenance.

The SNAI is built around two complementary pillars intended to counter depopulation trends: strengthening essential services and promoting place-based local development projects[111]. The latter includes objectives such as improving residents' well-being, increasing employment, reactivating territorial capital, reducing the social and environmental costs of land abandonment and progressive loss of human presence, and reinforcing local development drivers[112]. In practice, the SNAI pillars shape the enabling context for interventions in historic villages, because demographic decline and weak services often reduce the resources, skills, and continuity needed to plan, deliver, and maintain upgrades. A dedicated Support Fund for Marginal Municipalities further complements the Strategy by enabling targeted actions in particularly disadvantaged contexts[113].

Assessments of the first implementation cycle often describe SNAI as an enabling framework for local development and policy innovation, primarily because it activated multi-level and multi-actor partnerships. In practical terms, it fostered alliances among local authorities, third-sector organisations, businesses, universities, and professionals through integrated co-design across essential service sectors. At the same time, implementation has been hindered by uneven territorial planning capacity, difficulties in inter-institutional coordination, and challenges in delimiting coherent areas and identifying complex local needs[114]. These constraints point to the need for a stronger strategic and coordinating role by Regional Administrations. In this direction, the National Strategic Plan for Inner Areas 2021 to 2027 (PSNAI) provides operational guidance and proposes an updated governance model, including enhanced national coordination and an emphasis on community involvement, framed as necessary to align interventions with shared needs and feasible local capacities[115].

While SNAI is primarily framed around services and place-based development, other national initiatives have approached small settlements through heritage-led and tourism-oriented narratives, which become increasingly prominent from 2017 onwards. The Ministry of Cultural Heritage and Tourism (MiBACT)[116] promoted 2017 as the "Year of Italian Villages"

111 Healthcare, education, and mobility are considered essential services.

112 Ministry for the Territorial Cohesion and the South 2021, pp. 5-13.

113 Italian Government 2021d.

114 Ministry for the Territorial Cohesion and the South 2025, pp. 73-75.

115 Ministry for the Territorial Cohesion and the South 2025, pp. 9-17.

116 Since 2021 the Ministry of Cultural Heritage and Tourism (MiBACT) has been converted in Ministry of Culture (MiC).





within the Strategic Tourism Plan 2017 to 2022, with the aim of increasing the visibility of villages and developing shared criteria and tools for their valorisation, including the Charter of Villages[117]. In parallel, civil society organisations have played an increasingly prominent role, shifting from early advocacy for historic centres to broader initiatives connecting landscape value, tourism strategies, quality labels, and community-based governance[118].

A further policy step is represented by Law 158/2017 ("Save the Villages")[119], which targets municipalities with up to 5,000 inhabitants, including aggregated municipalities[120], with the stated aim of countering depopulation while safeguarding residents, services, and productive activities[121]. The law established a dedicated Fund[122] and was followed by implementing measures, including the National Plan for the Redevelopment of Small Municipalities approved by the Prime Ministerial Decree of 16 May 2022[123]. This decree, the latest in a series implementing the law, opened the call for project proposals to eligible municipalities[124]. As stated by the Minister for Civil Protection and Marine Policies, Nello Musumeci, the overarching goal of this strategy is to break the vicious cycle of depopulation, which is both a cause and consequence of economic, urban, and social decline resulting from the abandonment of settlements[125]. However, several accounts highlight delays and limited uptake of resources, pointing to a recurrent gap between legislative intent and operational delivery[126]. In particular, the lag between the law's enactment and the issuance of implementing decrees complicated

117 MiBACT 2017, point A.2.3. The Charter was drafted by the Coordination Committee for Tourist Villages, a body connecting all institutions involved in the regeneration of small settlements, including bodies such as the Directorate-General for Tourism and the MiBACT, but also associations active in village enhancement.

118 ANCSA 2024; I Borghi più belli d'Italia 2025; Borghi Autentici d'Italia n.d.; Touring Club Italiano n.d. Over the past few decades, civil society organisations such as the National Association of Historic-Artistic Centres (ANCSA), Touring Club Italiano, I Borghi più belli d'Italia and Borghi Autentici d'Italia, have played an increasingly prominent role in the protection and promotion of Italy's small villages, not only through institutional advocacy but also by fostering broader public awareness and cultural engagement.

119 Italian Government 2017b.

120 Italian Government 2000. An aggregated municipality is a public body formed by two or more municipalities to jointly carry out functions and services within their local jurisdiction.

121 Italian Government 2017b, article 1, paragraph 2.

122 *Ivi*, article 3 paragraph 8; Sau 2018, pp. 3-5. The Fund for the Structural, Economic and Social Development of Small Municipalities targets towns facing vulnerabilities such as depopulation, low population density, or hydrogeological risk, and finances measures ranging from infrastructure safety and public-building upgrades (including energy efficiency and renewables) to the restoration of historic centres and the safeguarding of cultural heritage.

123 Italian Government 2022.

124 Italian Goverment 2021c.

125 Palazzo Chigi 2023.

126 e.g. Monardo 2023, p. 58. The law allocated an initial fund of 100 million euros, subsequently raised to 160 million in 2023.

the timely deployment of funding[127]. This implementation gap is particularly consequential for small municipalities, where limited technical capacity and liquidity constraints can delay, scale down, or prevent the delivery of building and public-space interventions.

More recently, the COVID-19 crisis has been widely discussed as a catalyst for renewed attention to marginal areas and smaller centres, linked to changing spatial preferences, environmental quality, and the expansion of remote working arrangements beyond the acute emergency phase. Within this broader debate, the functional adaptation and energy upgrading of existing and historic housing stock gained further policy visibility, reinforcing incentives and measures that bring new challenges and questions to the foreground[128]. For this research, the central point is to recognise how rapidly evolving socio-spatial expectations may increase pressure for transformation within fragile historic fabrics, potentially without adequate place-based guidance. In this context the post-COVID phase is a contextual accelerator that intensified demand for adaptation in historic housing and urban space.

Within Next Generation EU[129], the Italian National Recovery and Resilience Plan (PNRR)[130] identifies cultural heritage as a key investment axis. Measure 2.1, "Enhancing the Attractiveness of Historic Villages", aims to support the revitalisation of villages in fragile and marginal areas through cultural regeneration and sustainable tourism[131]. The call for proposals was structured around two lines: Line A, which funded one regional pilot project per region[132], and Line B, which supported a larger number of local projects and related enterprise initiatives[133]. These measures combine interventions on heritage and public space with support for cultural and creative activities

127 As contained in the plea ANCI *et al.* (2018), just one year after the law's enactment, numerous local administrators and territorial entities were already calling for a possible acceleration of its implementation process.

128 Pracchi, Oteri 2023, p. 165. E.g. Facades Bonus ("Bonus facciate", established by Italian Government 2019), Bonus 110% (established by Italian Government 2020a).

129 European Union 2025.

130 Italian Government 2021a; Italian Government 2021b.

131 Italian Government 2021e. Intervention 2.1 is led by the Ministry of Culture (MiC). A Village Coordination Committee, established after the 2017 Charter of Villages and integrated into the MiC in 2021, oversees initiatives for historic villages, including those under the PNRR. The programme is linked to wider agendas on digitalisation and innovation and is framed as consistent with Law 158/2017, the SNAI, and SDGs 8 and 11.

132 MiC 2021, pp. 1-6; Severgnini 2022, pp. 17-18. Line A allocated €420 million to 21 regional pilot projects (one per region), selected by regional authorities for villages (max 300 housing units) affected by depopulation or abandonment. Projects combined refunctionalisation and new infrastructure to improve liveability.

133 MiC 2021, pp. 6-9; Menegus 2022, pp. 933-934. Line B allocated €580 million to 229 villages, supporting eligible municipalities (up to 5,000 residents, individually or aggregated) and micro, small and medium-sized enterprises locating in the selected villages. Projects prioritised cultural, environmental and tourism impacts, community engagement, and alignment with Line A outcomes.





and services with tourism potential, and they are framed as contributing to broader objectives on employment and inclusive settlements[134].

A distinctive feature of the PNRR is its promotion of an innovative governance model grounded in collaboration and co-programming between public administration and private actors[135]. This approach not only informs the implementation of the PNRR itself but also reflects a broader shift in European programming cycles, which increasingly embrace such participatory frameworks. This model encourages the active engagement of local communities, businesses, and third-sector organisations in the valorisation of territorial cultural assets, with reference to the principles contained in the Faro Convention[136]. Moreover, this marks the first initiative in which the Ministry of Culture engages with marginal areas through substantial financial resources. It represents a significant shift from previous cultural and tourism policies targeting inner areas and smaller settlements, particularly in terms of the amount of funding[137]. At the same time, the PNRR approach has been criticised for limited capacity to foster inter-municipal coordination, particularly where competitive selection mechanisms focus on single municipalities[138]. This point matters because it introduces a governance tension with longer-term cohesion frameworks such as SNAI, which explicitly prioritise overcoming fragmentation through coordinated territorial arrangements[139]. It also raises a substantive question for fragile inner-area settlements: whether a model centred predominantly on tourism and cultural regeneration is sufficient for systemic reactivation, or whether it should be complemented by attention to enabling infrastructures and long-term services, including contemporary challenges such as energy provisioning[140]. Additional concerns include limited transparency in regional selection processes, short timelines that disadvantaged less equipped municipalities, and financial constraints linked to upfront expenditure, which led some administrations to withdraw[141].

134 Italian Government 2021a, p. 112.

135 Italian Government 2020b. The adoption of the Special Public-Private Partnership mechanism, designed to enhance cultural heritage through the involvement of qualified private stakeholders, has emerged as a key evaluative criterion for projects within PNRR.

136 Council of Europe 2005; Landi 2023, p. 8.

137 Pracchi, Oteri 2023, p. 200.

138 UNCEM 2022. The PNRR funding mechanisms were widely criticised for their limited capacity to support inter-municipal systems by organisations such as UNCEM (the Italian National Union of Mountain Municipalities, Communities, and Bodies) and by numerous mayors of small municipalities in inner areas.

139 Pracchi, Oteri 2023, p. 172.

140 Pracchi, Oterni 2023, p. 193.

141 Menegus 2022, p. 935; Pracchi, Oteri 2023, p. 176.

## 1.3 Legal Framework and Policies for Conservation and Interventions in Historic Villages in Sardinia

This section maps the legal and policy framework governing conservation and transformation in Sardinia's historic villages and centres, which form the geographical focus of this study. The Region has developed a substantial set of plans, programmes, and funding streams for historic cores; however, regional and academic accounts frequently describe implementation as uneven, shaped by overlapping instruments and variable municipal capacity. For this reason, the section first clarifies the hierarchy from national heritage and planning law to the Regional Landscape Plan and municipal tools, making competences, procedures, and areas of discretion explicit. It then highlights how these frameworks are translated into practice through programmes and funding cycles, with the aim of clarifying what types of interventions are admissible, who authorises them, and where mismatches between policy intent and local delivery can affect feasibility in small municipalities.

### 1.3.1 Laws, Plans, and Instruments: a Framework for Historic Centres in Sardinia

Since the 1990s, the Autonomous Region of Sardinia has developed a dedicated policy framework for the recovery of historic centres, starting with Regional Law No. 29/1998[142]. This law provided an early regulatory and funding basis for municipal interventions in historic urban areas, framing the "*recovery, requalification, and reuse of historic centres and minor historic settlements*"[143] as a strategic regional interest, also in relation to the reuse of existing real estate assets and the containment of land take[144]. It introduced operational tools such as a Regional Inventory of Historic Centres and a multi-year programme to co-finance municipal actions, structured around integrated programmes for historic centres, upgrading of infrastructure and services, and the restoration of historic housing units[145]. In this sense, the regional approach combined conservation objectives with wider aims related to settlement quality and the continued use of the existing building stock.
In 2006, Sardinia approved the Regional Landscape Plan (RLP), the first landscape plan adopted in Italy under the updated national framework[146] and

142 Autonomous Region of Sardinia 1998.

143 *Ivi*, article 1.

144 *Ibidem.*

145 *Ivi*, articles 5, 6, 9, 13, 14 and 15.

146 Autonomous Region of Sardinia 2006a; Leoni, Zoppi 2016, p. 178. The Sardinian Regional Landscape Plan entered into force in 2006 following its approval and publication in Bollettino Ufficiale della Regione Autonoma della Sardegna, No. 30, dated 08 September 2006.





still one of the few fully in force nationwide[147]. The RLP places landscape conservation at the centre of territorial governance and aligns this objective with principles advanced by the European Landscape Convention, including the recognition of landscapes shaped by long-term human settlement. Within this perspective, landscape protection is not treated solely as a safeguard of heritage assets, but as a condition that should be integrated into spatial planning and, where feasible, supported by collaboration with local communities[148]. This innovative vision draws inspiration from the principles of the European Landscape Convention, particularly its emphasis on the relationship between predominantly natural landscapes and those shaped by human settlement, adapting these concepts to the specific territorial and cultural context of Sardinia. Within this framework, landscape is conceived not merely as a heritage asset but as a strategic driver of local development, requiring its integration into territorial planning policies. Such integration is to be pursued through active collaboration with local communities, promoting a participatory approach to landscape transformation[149]. In this way, the RLP framework establishes continuity with the Region's earlier objectives of "cultural sustainability", echoing the definition proposed by the Franceschini Commission in the 1960s[150].
A critical feature of the Sardinian RLP is that it has been developed only for coastal areas, reflecting where demographic concentration and development pressures have historically been most intense[151]. Although the Plan envisaged a subsequent extension to inner areas, this second phase has not yet been implemented[152]. At the same time, the RLP explicitly calls for planning approaches capable of reconciling contemporary functional needs with the protection of contextual values and local identity, including in small historic villages and in minor building fabrics that are often more exposed to decay and functional obsolescence[153].
Within the RLP framework, historic cores are addressed through the identification of "Centres of Ancient and Early Formation" (also referred to as the "Original Core"), delineated through historical cartography and later refined through technical consultation with municipalities[154]. Once formally recognised, these perimeters trigger landscape protection even in the absence

147 FAI 2022. To date, the Sardinian RLP is one of the few landscape plans that have been formally approved and are currently in force across the national territory, alongside those of Apulia, Tuscany, Friuli Venezia Giulia, Piedmont, and Lazio. Lazio's RLP remains provisionally adopted and is beset by various issues.

148 Autonomous Region of Sardinia 2006c, p. 1.

149 *Ivi*, p. 192.

150 *Ivi*, pp. 168-169.

151 Leoni, Zoppi 2016, p. 178.

152 Autonomous Region of Sardinia 2006c, p. 3.

153 Atzeni *et al.* 2022, p. 5.

154 Autonomous Region of Sardinia 2006c, p. 122; Autonomous Region of Sardinia 2008a; Autonomous Region of Sardinia 2008b.

of a specific Declaration of Significant Public Interest[155]. In practice, strict delimitations can produce uneven regulatory conditions between what falls inside and outside the perimeter, with socio-economic implications where constraints differ substantially[156].

At the municipal level, the Detailed Plan of the Historic Centre (DPHC) is the key instrument expected to translate landscape constraints into operative rules[157]. The DPHC must be consistent with the municipal planning framework and aligned with the RLP, and only after a compliance check can the interventions it regulates be authorised[158]. Where explicitly provided, demolition and reconstruction may be allowed, subject to the applicable planning and landscape instruments and to the opinions of the competent heritage authorities[159]. The DPHC typically codifies local morpho-typological characteristics and assigns a differentiated level of transformability, with the aim of steering change towards compatibility with the wider landscape and urban context (including density, heights, alignments, and the relationship between built volumes and open spaces)[160]. Importantly, the plan has a regulatory and guiding function, but it cannot require the demolition of a lawfully existing building. Some mechanisms may allow compensatory actions, for example linking new construction or expansion to the removal of elements considered incongruous, yet these solutions tend to be difficult to activate where costs fall entirely on private owners[161].

Where a DPHC is absent or not compliant, the range of admissible works is typically restricted to maintenance, conservative restoration and rehabilitation, and limited renovation of internal spaces[162]. Changes of use in historic centres are generally admissible only where the DPHC provides for compatible

155 The Declaration of Significant Public Interest is the legal instrument designated for the protection of the landscape, specifically concerning assets or areas that exhibit features and characteristics deemed to be a tangible and visible representation of national identity. It is regulated by articles 138 and 139 of the Urbani Code (Italian Government 2004).

156 Atzeni *et al.* 2022, p. 4. The Territorial Plan of Tuscany (Region of Tuscany 2015) recognises and extends attention to the area included in a buffer zone of 300 m from the perimeter of "Zone A", which is strongly connected on a morphological, perceptual, identity and historically functional level to the historic core. In this way the Region addresses some of the controversies brought by the perimetralisation.

157 Autonomous Region of Sardinia 2007a.

158 The verification of the compliance of municipal urban planning instruments with the PPR is governed by Autonomous Region of Sardinia 2008a.

159 Italian Government 2001a, article 2-bis, paragraph 1-ter.

160 Autonomous Region of Sardinia 2006d, articles 52 and 53, paragraph 3; Colavitti, Serra 2017, p. 82.

161 Colavitti, Serra 2017.

162 For the national classification of building intervention categories (including ordinary and extraordinary maintenance, conservative restoration and rehabilitation, and building renovation), see Italian Government 2001a, Art. 3. For the definition of "restoration" in the heritage protection framework, see Italian Government 2004, Art. 29(4). See also Autonomous Region of Sardinia 2007b, pp. 3–5, for regional guidance and terminology.





restoration or renovation measures and where the proposal complies with the municipal planning framework (GDP). In addition, a change of use typically requires a building permit issued by the municipality following a compliance assessment against planning and conservation criteria[163]. While these constraints aim to avoid harmful transformations, they can also make functional adaptation more difficult, particularly in contexts where buildings need upgrading to remain in use[164]. Especially in small municipalities, DPHCs have often struggled to operate as strategic tools connecting conservation rules to medium and long-term development objectives, partly because of limited staff capacity, the complexity and duration of alignment procedures, and the limited use of participatory processes[165]. For this reason, an approach that involves continuous monitoring of the current urban condition would be crucial to better assess planning proposals and to strengthen both management capacities and operational procedures[166]. In this context, digital tools have been developed to support planning, such as the eBiddas platform, which compiles indicators related to historic cores and municipal heritage[167].

Finally, tensions emerge between the RLP principles and subsequent regional measures that introduced exceptional building incentives, notably the so-called Piano Casa[168], first adopted in 2009[169] and repeatedly extended through later amendments (including Regional Law 17/2020)[170]. Piano Casa allows specific forms of alteration and volumetric expansion, including derogations from certain planning limits, and in historic cores it sets conditions intended to limit eligibility to buildings considered inconsistent with the typological and architectural character of the context[171]. However, these provisions can conflict with landscape-oriented criteria that prioritise broader spatial relationships and the balance between built volumes and open space. As a result, incentives designed at the scale of the individual building do not automatically translate into coherent regeneration outcomes at the scale of the historic fabric[172].

163 Italian Government 2001a, article 10, paragraph 1.

164 Atzeni *et al.* 2022, p. 5.

165 Leone, Zoppi 2014; Leone, Zoppi 2016a.

166 Atzeni *et al.* 2022, pp. 5-6.

167 eBiddas n.d. Unfortunately, although the platform was intended to be enhanced with new functionalities, as of September 2025, the platform does not appear to have been updated with the additional functionalities originally envisaged.

168 Italian Government 2008b, article 11.

169 Autonomous Region of Sardinia 2009a. The extraordinary measure was first issued to stimulate the construction sector and support the economy after the 2008 global crisis.

170 Autonomous Region of Sardinia 2020.

171 Autonomous Region of Sardinia 2009a, article 2, paragraph 1. Piano Casa allows the adjustment and volumetric expansion, up to 20% per unit, of residential buildings, facilities serving residential use, and productive structures

172 Colavitti, Serra 2017, pp. 82-83.

### 1.3.2 Implementation in Practice: Programmes, Funding Cycles, and Inner-Area Strategies

Following the entry into force of the RLP, several regional initiatives have supported the regeneration of historic centres, including historic villages. These initiatives, initially linked to Regional Law No. 29/1998, incorporate the provisions of the RLP and integrate them into their strategic objectives. These policies have enabled interventions across the two principal dimensions that define the urban quality of a territory: the redevelopment of the *urbs*, referring to the material components of the settlement; and the regeneration of the *civitas*, encompassing collective life, service networks, and social relations[173]. The DOMOS (2006) and BIDDAS (2008) calls for proposals focus on countering depopulation by improving the residential quality of Sardinia's historic centres and revitalising their economic and social vitality, combining actions on the built stock with measures supporting everyday liveability. Both programmes provide funding for interventions that significantly contribute to the enhancement of historic building stock, aiming to restore a balanced mix of services and residential functions in small towns, promote the reuse of abandoned properties, and achieve a certain level of landscape quality[174].
Similar objectives were pursued in the 2000–2006 EU programming cycle through the Regional Operational Programme (ROP). Within the ROP for Sardinia, Measure 5.1, under Axis V, was dedicated to urban area policies. Sub-measure 5.1.c, titled "Strengthening of smaller centres", aimed to establish networks among service infrastructures in small towns which play a crucial role as territorial outposts or productive clusters, being comparable to intermediate urban centres. Within this framework, several initiatives were launched, including successive calls, such as the "2000/2001 Call", the "ROP 2003 Call", the "Quality Projects Call", and the "CIVIS Call"[175]. The latter, in particular, promoted a network-based strategy for small urban centres and advanced the formation of inter-municipal networks, encompassing contiguous municipalities or thematic networks of non-contiguous centres united by a shared development goal in the field of distributed hospitality[176].
Within the ROP cycle, in 2004, the Region launched a new approach to local development based on integrated planning, which entailed the mobilisation of public–private partnerships. This phase marked a central moment for multi-level territorial collaboration through the creation of territorial planning laboratories and technical support units embedded within provincial administrations, which also facilitated direct engagement with local stakeholders[177]. Still, as part of the ROP Sardinia, Axis III Measure 3.9

173 Autonomous Region of Sardinia 2013b, p. 17.
174 *Ivi*, pp. 33-35.
175 *Ivi*, pp. 91-93.
176 Autonomous Region of Sardinia 2013a, pp. 39-40.
177 Autonomous Region of Sardinia 2013b, p. 115.





"Specialised training on landscape protection and capacity building for public administration" led to the publication in 2009 of the series Handbooks of the Recovery of Historic Centres, promoted by the Region in collaboration with Sardinian universities. Each handbook provides analysis and guidelines for a specific area of the region, referencing a particular traditional construction technique[178]. Through these handbooks, the Region aims to provide municipalities with a practical tool for preserving identity and enhancing traditional historic buildings.
Moreover, through the activities of the Observatory on Historic Centres and Urban Transformations of Sardinia, established by Regional Law No. 29/1998 with research and study functions concerning interventions in urban centres[179], further resources were developed in collaboration with the universities: the Guidelines for Landscape Protection in Centres of Ancient and Early Formation. These consist of two volumes dedicated respectively to intervention criteria for building conservation and to the maintenance and regeneration of public spaces[180]. The work continued under the 2007–2013 ROP, specifically within Axis V (Urban Development). This axis pursued strategies aimed at requalifying Sardinia's urban system, both to prevent further dispersion of urban areas and to strengthen and reconstruct the identity-based and polycentric characteristics of urban systems. Axis V also supported the development of smaller settlements, following a logic of polycentric rebalancing and counteracting depopulation[181].
In both ROPs, the interventions primarily focused on actions such as the upgrading of street paving, the adaptation of underground utilities, and the restoration of historically significant buildings, as shown by the examples in Figs. 10 and 11. Some projects also involved the regeneration of parks and green spaces, as well as the establishment of local laboratories[182]. During this phase, interventions have often been described as poorly coordinated and fragmented, marked by limited convergence of strategies and actions and a lack of inter-municipal cooperation, particularly in relation to the inclusion of territories affected by severe marginalisation[183]. More recently, efforts have been directed toward reversing this trajectory through strategies grounded in an integrated, cross-sectoral development perspective, aiming to ensure a more coordinated vision for the actions to be undertaken. Between 2015 and 2016, the Autonomous Region of Sardinia, in line with the priorities set by the European Commission under the Europe 2020 strategy aimed at promoting smart, sustainable, and inclusive growth, undertook a process to

178 See e.g. Sanna, Cuboni 2009 for studies on stone architecture in the eastern area or Sanna, Atzeni 2009 for raw earth architecture in the southern area.
179 Autonomous Region of Sardinia 1998, article 19, paragraph 1-ter.
180 Autonomous Region of Sardinia 2009b; Autonomous Region of Sardinia 2009c.
181 Cannas *et al.* 2017, p. 466.
182 *Ibidem*.
183 *Ivi*, p. 468.



**Fig. 10**
*Redevelopment of the primary school and selected streets in the historic centre of Sardara (SU). Source: Autonomous Region of Sardinia 2013b, p. 75.*

ensure the effective regional implementation of EU directives[184].
The development of inner areas falls within the scope of the Europe 2020 Strategy, a particularly critical issue for the Region of Sardinia. In particular, the implementation of regional policy for the development of inner and rural areas is carried out through the National Strategy for Inner Areas (SNAI) and the Territorial Programming framework or Regional Strategy for Inner Areas (SRAI), which concentrate resources on selected objectives at territorial and supra-local scales. Territorial Programming involves only municipalities that are formally associated within Unions or Mountain Communities, and supports the bottom-up definition of development projects, with the active participation of local enterprises. Territorial entities are allowed to address a wide range of thematic areas in their proposals, including essential services, sustainable mobility, digital infrastructure, green communities, and renewable energy sources. Given the absence of competition among territories in this specific case, all eligible areas submitted expressions of interest, and the majority successfully developed their own Territorial Development Project and Programme[185].
Concerning the 2014–2020 cycle of the National Strategy for Inner Areas (SNAI), the selected territories in Sardinia were "Alta Marmilla" (province of Oristano) and "Gennargentu Mandrolisai" (province of Nuoro) (Fig. 12). In the Alta Marmilla area, the response to depopulation is centred on younger generations, with investments in an open innovation ecosystem aimed at creating new entrepreneurship with creative potential. This strategy

184 European Union 2017; Cannas *et al.* 2017, p. 462.

185 Autonomous Region of Sardinia 2014.







**Fig. 11**
*Regeneration of Via Riarredu and Via Roma in the historic centre of the Municipality of Aggius (OT). Source: Autonomous Region of Sardinia 2013b, p. 119.*

is complemented by the cultural sector, through the establishment of a management network for cultural heritage, organised around four thematic areas, including one dedicated to landscape[186]. The Gennargentu-Mandrolisai territory builds its strategic vision on fundamental citizenship rights and introduces new cultural and productive processes to strengthen territorial competitiveness, rooted in its predominantly rural identity[187].
These areas were reconfirmed for inclusion in the 2021–2027 programming period, reflecting the strong consensus among the administrations on the need to advance the implementation of SNAI from its experimental phase to a consolidated framework, updating the adopted strategies. The 2020–2024 Regional Development Programme had already set out, as part of its strategy for enhancing Sardinia's territorial identity, the adoption of an integrated territorial approach, aimed at continuing and strengthening the development of these strategies. This approach was reaffirmed in Regional Government Resolution No. 39/44 of 30 July 2020, titled "Regional Development Programme 2020–2024. Strategy 3.3.3: Territorial Strategy and Local Development", which also envisaged the possible extension of the strategy to territorial areas not included in the previous programming phase[188]. In the 2021–2027 cycle, the areas of "Barbagia" (province of Nuoro) and "Valle del Cedrino" (province of Ogliastra) have also been included, falling within "peripheral" and "ultra-peripheral" areas (Fig. 12). Both territories are characterised by the tight link between nature and economy, which has

186 Unione di Comuni "Alta Marmilla" n.d.

187 Italian Government n.d.; Renoldi, McComas 2023, pp. 113-115.

188 Autonomous Region of Sardinia 2021a, pp. 5-6.

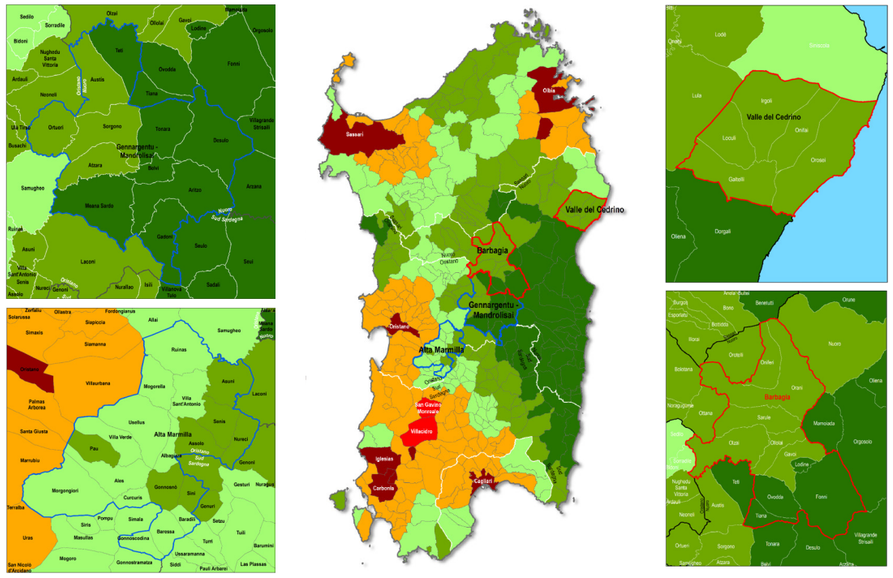



**Fig. 12**
*SNAI areas in Sardinia, for the cycle 2014-2020 (in blue) and the cycle 2021-2027 (in red). Source: FormezPA 2022, pp. 5, 9, 11, 13, 14.*

inspired their territorial development projects, aimed at the preservation of natural and cultural resources in synergy with human activities[189].
Several studies highlight that, although the identification of a shared area-based strategy is foreseen, certain concerns persist[190]. The risk of discontinuities and territorial "voids" remains tangible, especially towards resolving the dualism between development in inland areas and that along the coastal zones. Moreover, evidence on effectiveness remains limited. Planning efforts have struggled to attract investors or generate employment capable of ensuring a better quality of life, despite the presence of significant environmental, historical, and cultural resources. Depopulation remains a concerning challenge, especially since the strategies have not yet offered credible guarantees of success and the local human capital, particularly the more educated, faces increasing difficulty in pursuing the professional paths for which they have trained.
Similar concerns, also observed at the national level, persist with regard to the measure targeting small villages under the National Recovery and Resilience Plan (PNRR)[191]. In Sardinia, this initiative involved the municipality of Ulassai, in the province of Ogliastra, which developed a project rooted in the enhancement of artistic, environmental, and identity-based heritage, as well as the quality of social relations[192].

189 Autonomous Region of Sardinia n.d.; Renoldi, McComas 2023, p. 115.

190 e.g. Cannas *et al.* 2017; Brundu 2022.

191 Cersosimo 2022; Corazza 2022; Renoldi, McComas 2023, pp. 122-123.

192 Municipality of Ulassai 2023.





## 1.4 The Semantics of the Term *borgo* and its Aesthetic Misconception

In Italian, the term *borgo* has undergone a long semantic shift. Early meanings referred to fortified settlements or defensive structures and, in later usage, to clusters of dwellings located outside city walls, sometimes overlapping with the sense of a suburb or an urban district[193]. Over time, the term expanded and its boundaries became less precise, with *borgo* increasingly used as a generic label for a small historic settlement rather than a category defined by clear morphological, historical, or administrative criteria[194].
This definitional ambiguity matters because contemporary national programmes addressing small settlements often mobilise the term without specifying what, exactly, qualifies as a *borgo*. As a result, eligibility and policy intent may rest on partially implicit assumptions[195]. For example, in the national discourse around village revitalisation, *borghi* have been associated with small municipalities (often up to 5,000 inhabitants) characterised by "authenticity", "uniqueness", and "beauty", foregrounding cultural value and attractiveness[196]. Within the National Recovery and Resilience Plan (PNRR), by contrast, *borghi* are framed more operationally as historic nuclei that retain a recognisable traditional structure and continuity of built fabric, and that include substantial portions of abandoned heritage buildings[197]. Both formulations leave open key questions, including the historical period implied by the label, the threshold between "historic nucleus" and "historic centre", and the socio-economic conditions that policies intend to address alongside built heritage.
In parallel, the contemporary use of *borgo* has progressively moved away from a primarily spatial and morphological meaning and has become increasingly tied to idealised aesthetic representations. In public narratives and in some policy framings, villages are frequently presented as picturesque and timeless, and this imagery becomes a lever for place branding and tourism-oriented revitalisation (Fig. 13). While such approaches can increase visibility and resources, they also risk narrowing "revitalisation" to image-making and short-term attractiveness, rather than engaging with the deeper conditions that sustain inhabited heritage, including everyday services, housing usability, local

193 Treccani 1930; Farinelli 2006, p. 13.

194 Pianigiani 1907.

195 Pracchi, Oteri 2023, p. 167.

196 MiBACT 2016.In 2017, the Ministry of Cultural Heritage and Tourism (MiBACT) defined *borghi* as "*Italian municipalities with no more than 5000 inhabitants, characterised by a valuable cultural heritage whose preservation and enhancement are of great importance to the national system, as they represent authenticity, uniqueness, and beauty, distinctive elements of Italy's cultural offering*".

197 MiC 2021, p. 4.Within the PNRR, *borghi* are described as "*settlements or historic nuclei that have retained the recognizability of their traditional urban structure and the continuity of their historic built fabric, and that contain substantial portions of abandoned heritage buildings*".

capacity for maintenance, and the long-term stewardship of the built fabric. In other words, the label *borgo* may implicitly steer attention towards what is immediately visible and marketable, even when the underlying challenges are structural and require coordinated, place-based action.

Recent critiques have described this tendency as a form of "borgomania"[198], arguing that it can freeze settlements into a timeless image and weaken their relationship with surrounding territories and networks. This critique is taken here as a warning about how language and imagery can influence the priorities of programmes and the expectations placed on small settlements. A related response has been to propose more neutral terms such as *paesi*, intended to better capture the heterogeneous and evolving character of communities and to reduce the aesthetic overtones that the word *borgo* has acquired[199].

For the purposes of this thesis, the term "historic village"[200] is adopted as a working translation of *borgo*. It is used to denote a small-scale settlement characterised by a historically rooted urban and architectural identity, where conservation is inseparable from continued use, liveability, and the capacity to manage change over time. This choice is not merely terminological: it clarifies that the study is concerned with inhabited heritage as a living system, and that interventions should be assessed not only in terms of visual preservation or attractiveness, but also in terms of feasibility, maintenance, and the conditions that allow long-term adaptation.

Building on the policy landscape outlined in this chapter and on the semantic ambiguity that surrounds the term borgo in contemporary programmes, a central question is how conservation aims can be translated into feasible interventions in marginal territories, where uneven services and administrative capacity shape delivery and long-term maintenance. This transition is also necessary because current initiatives often mobilise heritage value through attractiveness and branding, while the conditions that sustain inhabited heritage are increasingly affected by environmental pressures and changing performance expectations. The next chapter therefore shifts from terms and frameworks to the environmental dimension of historic settlements, outlining how climate and context have shaped urban and architectural forms and how these lessons can inform contemporary strategies that integrate conservation, adaptation, and long-term stewardship.

198 Barbera *et al.* 2022.

199 Clemente 2022, p. 19.

200 Office for National Statistics 2025. In English, the term "village" typically refers to a settlement situated within a rural context. For instance, the Rural Urban Classification of Local Authority Districts (RUCLAD) in the United Kingdom categorises Census Output Areas into ten distinct classes, ranging from major urban conurbations to rural villages.








**Fig. 13 (next page)**
*The recent tourism-oriented vocation of historic villages, revealed by souvenir shops and the proliferation of B&Bs, Posada (NU), Sardinia. Source: tripadvisor.com*

# Chapter 2.
# Historical Architecture and Environmental Context: Traditions, Challenges, and New Perspectives

From the mid-twentieth century to the present, the relationship between historic settlements and their environmental context has been reframed. Scholarship has recovered how traditional urban and architectural forms embedded climate knowledge in fabric, layout, and use, while contemporary agendas on sustainability and climate action have raised expectations around performance, resilience, and equity. Taken together, these trajectories intersect with pre-existing weaknesses in marginal territories, where demographic decline and limited institutional capacity amplify environmental risks and policy gaps.

Reinterpreting traditions under current climatic, social, and economic conditions can therefore provide an operational resource for design and policy. Strategies that extend the life and usefulness of existing stock through maintenance, retrofitting, and adaptive reuse support an understanding of heritage management as a platform for sustainable planning rather than an obstacle. In this sense, "performance" is not limited to energy targets, but also concerns the continuity of use, the affordability of upgrading, and the ability to maintain interventions over time, especially in small and ageing communities.

At the same time, continued land take and post-war patterns of expansion have contributed to landscape deterioration and environmental stress, often weakening the relationship between historic fabrics and their territorial context. Addressing this contradiction requires regulatory and design approaches that reconcile energy improvement and risk mitigation with heritage values, while avoiding one-size-fits-all solutions that overlook local construction logic, climatic specificity, and capacity constraints.

In this context, the chapter has a twofold objective. First, it outlines how climate and environment have historically shaped settlements and buildings, drawing operational lessons that are relevant to contemporary interventions in historic villages. Second, it situates these lessons within current sustainability and governance frameworks, including the growing emphasis on integrated approaches and participatory processes that treat communities as co-producers of significance and stewards of long-term outcomes.



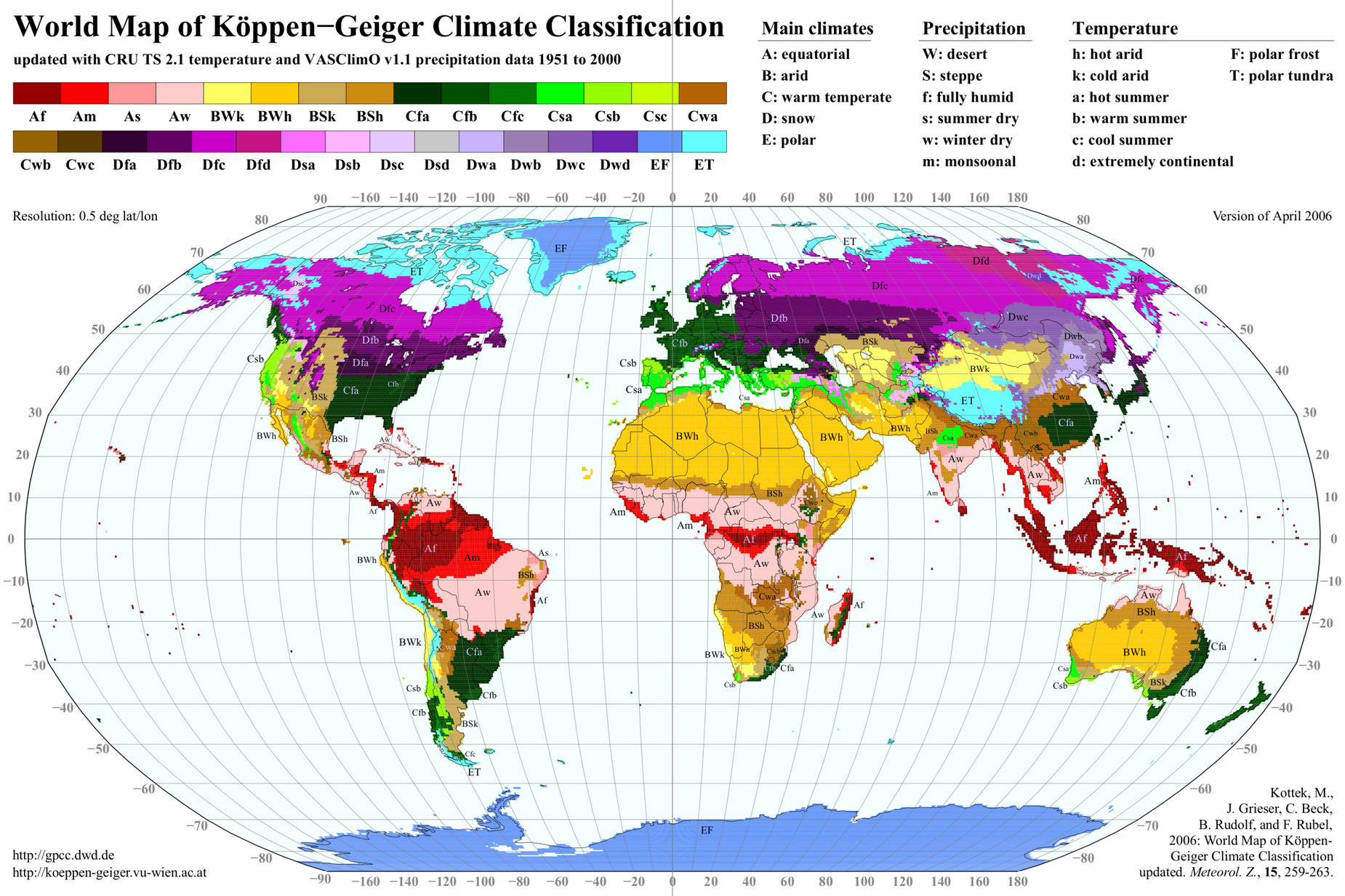


## 2.1 The Influence of Climate on Historic Urban Shape and Architecture: Lessons from Tradition

Historically, before the widespread adoption of mechanical systems for microclimatic control, architecture itself contributed to thermal comfort and the habitability of both indoor and outdoor spaces through form, materials, and construction techniques. Traditional architecture developed over centuries a set of empirical principles which, by efficiently exploiting boundary conditions, available materials, geometric factors, and the technology of construction elements, provided the highest possible levels of comfort while simultaneously meeting diverse requirements (structural stability, durability, thermal regulation, acoustic insulation, functional distribution, etc.)[1]. The rules shaping the built environment were not arbitrary, but deeply rooted in shared practices that had been refined and transmitted over time. Adhering to traditional building methods thus meant not only respecting pre-existing structures, but also contributing to their continuity as part of a common morphological language, albeit one in constant evolution[2]. The historic settlement thereby embodies the cultural and expressive values of a community in a specific time and place[3].

The construction of a settlement in relation to local climatic conditions was based on a series of considerations at both the urban and building scales. At the urban scale, the orientation of buildings and the topographical configuration of the terrain were assessed to maximise the benefits of solar exposure and ventilation, or to provide shelter from them. Vegetation played a strategic role in harnessing prevailing winds or creating shaded areas. Proximity to bodies of water could serve as a means of regulating air temperature, while the choice of construction materials and finishes aimed to exploit the thermal properties of surfaces, such as their capacity to absorb or reflect solar radiation[4]. At the building scale, envelope materials were required to deliver adequate thermal performance, particularly in terms of transmittance (limiting heat loss), thermal inertia (and related lag effects), and stable indoor temperature distribution (promoting a steady-state thermal condition that ensures internal temperature stability). Finally, the design of openings facilitated air exchange, promoting cooling and humidity reduction, and enabled the capture of solar energy indoors to increase air temperature naturally[5].

1 Zaffagnini 1993, p. 7; Desogus *et al.* 2016, p. 574.
2 De Bernardinis 2011, p. 9.
3 Vitiello 2012, p. 27.
4 Lucchi, Pracchi 2013, p. 36.
5 *Ivi*, p. 54.




Kottek, M., J. Grieser, C. Beck, B. Rudolf, and F. Rubel, 2006: World Map of Köppen-Geiger Climate Classification updated. *Meteorol. Z.*, **15**, 259-263.

**Fig. 14**
*World map of Köppen-Geiger climate classification.*
*Source: Kottek et al. 2006, p. 261.*

### 2.1.1 Climate-Specific Typologies and Operational Lessons

Although the configuration of the urban fabric was the synthesis of many factors beyond climate (social and functional needs, cultural trends, religious influences, economic considerations, etc.), with appropriate simplifications, it is possible to identify recurring architectural bioclimatic solutions[6] in analogous climatic contexts, at both urban and building scales. For the purposes of this thesis, these recurrent solutions are read as operational principles that can inform contemporary interventions, rather than as typological models to be replicated.

In cold regions (Fig. 14, letter D), compact urban forms with narrow, curving streets protect against wind and reduce heat loss, often taking advantage of the shelter offered by hillsides and mountain slopes. At the building scale, compact layouts further limit heat dispersion and enhance solar gain, frequently complemented by dark-coloured exterior finishes or insulating layers of wood, earth, or straw embedded within the walls[7] (Fig. 15).

In hot-arid climates (Fig. 14, letter B), houses with thick walls are built in close proximity to one another to reduce the surface exposed to solar radiation, while private courtyards, squares, and narrow, tortuous streets regulate ventilation and lighting. At the building scale, enclosed, massive walls with high thermal inertia attenuate diurnal temperature swings (Fig. 16). Roofs, whether heavy or lightweight, are sometimes equipped with specific devices, including sun sails or wind towers, designed to address shading and ventilation requirements (Fig. 17). Dwellings are often organised around a central patio, which enhances air movement and facilitates the upward expulsion of warm air. Patios may incorporate water features such as pools or fountains to increase relative humidity, as well as transitional spaces such as porticoes and loggias that provide shaded areas[8].

In hot-humid contexts (Fig. 14, letter A), lightweight, elevated, and spaced dwellings facilitate heat dissipation and air circulation. At the building scale, breathable walls promote air circulation and moisture dissipation, while steeply pitched roofs ensure rapid rainwater runoff[9] (Figs. 18, 19).

In temperate zones (Fig. 14, letter C), traditional architecture developed strategies to cope with highly variable climatic conditions, characterised by hot and humid summers, cold winters, and two milder transitional seasons.

6 The term bioclimatic originates from bioclimatology, a discipline introduced by Köppen in the early twentieth century to describe the distribution of vegetation in relation to specific regions of the planet. Bioclimatology can be defined as the study of the connections between climate and life, and of the ways in which humans inhabit the Earth while taking into account different climatic conditions. In this context, bioclimatic solutions refer to a set of architectural design strategies and construction techniques that address thermo-hygrometric comfort in buildings and settlements by harnessing the natural resources of the site.

7 *Ivi*, pp. 36-40; 55-65.

8 *Ivi*, pp. 53, 68-74.

9 Coch 1998, pp. 81-83.





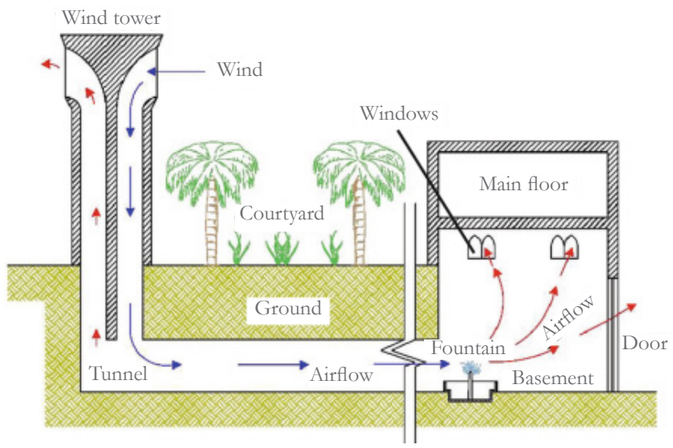


**Fig. 15**
*Corippo (Switzerland), an alpine village located at the between two valleys.*
*Source: espazium.ch*

The structure of both settlements and buildings, therefore, had to be flexible, incorporating solutions capable of mitigating both winter cold and summer heat. At the urban scale, many settlements exhibit a compact morphology with narrow, winding streets (Fig. 20). For Mediterranean towns, a modest width to height ratio typically yields better daytime thermal condition: this configuration maximises shading and reduces the surfaces directly exposed to intense solar radiation in summer, while also favouring heat retention during winters; effective designs balance these effects with orientation, surface materials, and vegetative shading. Street orientation often responds to prevailing summer breezes, enabling natural ventilation during the warmer months. In some regions of the Mediterranean climatic zone (Fig. 14, letters Csa, Csb), such as Greece and South Italy, the use of light-coloured façades, pavements, and roofs further contributed to reducing indoor heat gain by reflecting solar radiation (Fig. 21). This strategy was particularly effective where dense urban fabric, strong natural ventilation, and the extensive shading of public spaces prevented the reflected radiation from overheating outdoor environments. Vegetation and water features play a significant role in bioclimatic regulation. Trees and pergolas provide shade and increase humidity, while fountains or pools located in courtyards or public spaces enhance evaporative cooling, which reduces air temperature by using the process of water evaporation. Deciduous plants, such as vines, are particularly effective, as they allow solar radiation to penetrate during winter when foliage is absent, while providing shade during summer months when leaves are present. The use of transitional













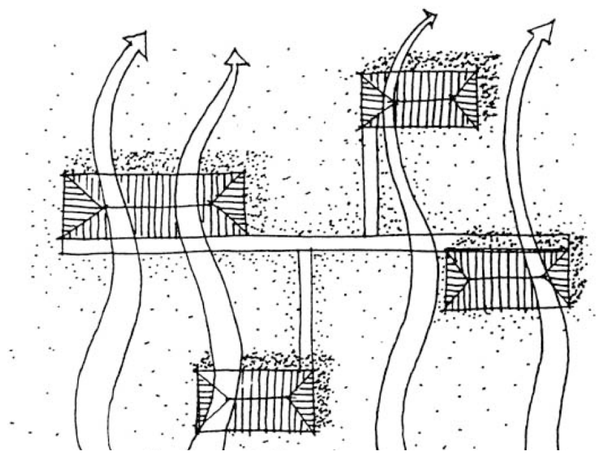



**Fig. 16 (previous page, above)**
*Ait-Ben-Haddou (Morocco), a fortified city located in the Sahara desert, on the slope of a hill. Source: earthviaggi.it*

**Fig. 17 (previous page, below)**
*Wind towers, devices for passive cooling and indoor ventilation, traditionally used in Middle Eastern regions to mitigate the effects of hot climates. Source: Dehghani-Sanij 2022.*

**Fig. 18 (above)**
*Kampung Naga (Indonesia), a traditional village city located on the slope of a hill. Source: wikipedia.org*

**Fig. 19 (below)**
*Layout of buildings in hot humid areas. Source: Coch 1998, p. 82.*

**Fig. 20 (above)**
*The compact settlement of Erice (TP), Sicily.*
*Source: westofsicily.com*



**Fig. 21 (below)**
*A narrow street in Monopoli (BA), Apulia.*
*Source: emmajaneexplores.com*








spaces, such as loggias or porticoes, is widespread and provides intermediate comfort conditions between outdoor and indoor environments[10].
At the building scale, dwellings commonly share party walls, and their orientation enables an internal spatial organisation in which rooms requiring continuous heating are placed along the southern façades, those benefiting from cooler conditions are located on the northern sides, and the remaining spaces are distributed along the eastern and western fronts. Built layouts are frequently structured around courtyards or patios, which further enhance ventilation and provide shaded microclimatic zones within the dwelling. Architectural elements such as loggias and pitched roofs regulate solar exposure across the seasons, providing additional climatic adaptability. Construction relied on locally available massive materials, such as stone, adobe, or thick masonry, selected according to regional availability and needs. These materials provide high thermal inertia, damping daily temperature fluctuations and ensuring cooler interiors by day and warmer ones after sunset. Openings in the building envelope are generally small and strategically positioned. Larger windows are typically oriented towards the south or east to capture the low winter sun, whereas north-facing and west-facing walls contain only a few small openings (or none at all) to reduce exposure to cold winds and afternoon sun. These openings are equipped with adjustable shading devices, ranging from deep eaves and cantilevered balconies to wooden shutters and perforated screens, which block or filter the high-angle summer sun while still admitting diffuse light and breezes. The layout and fenestration also facilitate cross-ventilation: aligned openings on opposite façades and internal doorways along prevailing wind directions enable fresh air to replace hot air, a practice often reinforced by deliberate user behaviour[11].
Nevertheless, at certain times of the year and specific times of day, passive measures alone, adopted in the construction of settlements and buildings to create a comfortable internal microclimate, were insufficient; even in antiquity, recourse was made to energy sources, foremost among them fire. This reminder is important because it avoids idealising "purely passive" traditions and highlights that comfort historically relied on a calibrated combination of spatial design, user practices, and limited energy inputs. As Banham observes, the human need for energy is not a modern phenomenon, but rather

"*energy has always been consumed at some time of the year, at some time of the day. Fires had to be lit in winter, lamps lit in the evening, muscle power for fans, water power for fountains during the hottest hours of the day*"[12].

Solutions for the efficient use of energy sources were often embedded in the spatial organisation of the dwelling, as was the case in most residential buildings. In Mediterranean houses, for instance, the kitchen was frequently

10 Lucchi, Pracchi 2013, p. 40.
11 Casanovas, Graus 2007, pp. 81-85; *Ivi*, pp. 65-66.
12 Banham 1969, p. 22.

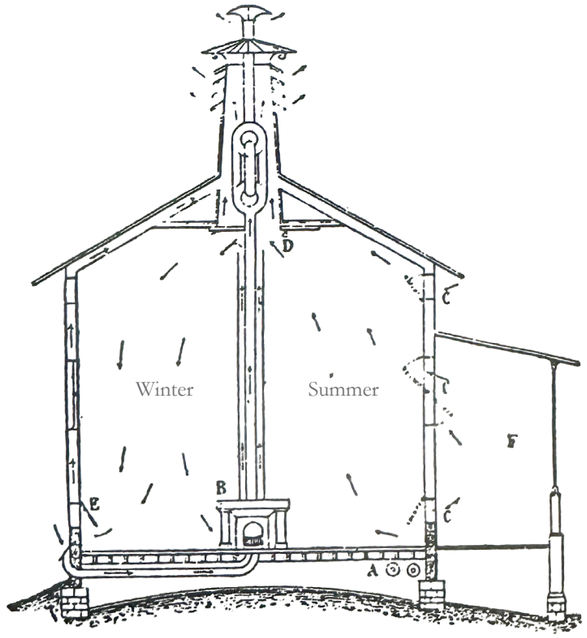



**Fig. 22**
*Representation of an elementar heating and ventilation system in an historic outpatient clinic. Warm air circulated within a service shaft, set in motion by combustion processes. From the shaft, the air entered the rooms, while ducts located beneath the floor and connected to the exterior supplied fresh air. In this configuration, the combustion products also heat the radiator, thereby inducing convective motion within the wall cavities. During the summer season, valve (D) at the base of the chimney is opened to discharge air directly through the extractor.*
*Source: Cetica 2004, p. 23.*

located on the lower floor beneath the bedrooms. This arrangement allowed the heat generated by the fireplace or stove to rise by natural convection, warming the cold sleeping areas before dissipating through the roof. In other, more specialised types of architecture, such as institutional, healthcare, or public buildings in larger cities, forms of "protoclimatisation"[13] were employed, consisting of rudimentary heating or cooling systems integrated into the construction (Fig. 22). In both situations, the thermal requirements of indoor spaces were addressed at the design stage, so that architecture and technical installations were conceived as a unified whole[14]. Before the advent of non-renewable energy sources, energy use was closely calibrated to the availability of local resources, and its controlled management ensured long-term sustainability.
Revisiting these historical techniques in the current context of the energy and climate crisis does not imply a nostalgic return to the past or merely preserving traditional practices. Instead, it highlights the importance of a conscious and adaptive use of environmental resources, translating recurring principles (compactness and shading, thermal mass and lag, ventilation paths, transitional spaces, and the role of vegetation and water) into criteria that can guide contemporary design and retrofit strategies[15].

13 Cetica 2004, p. 8.
14 Banham 1969, p. 22.
15 De Bernardinis 2011, p. 9.





### 2.1.2 Climatic and Morphological Variations in Traditional Settlements of Sardinia

Sardinia lies in the western Mediterranean basin and covers 24,098 km². Its landforms are diverse, with hills occupying the largest share of the territory, followed by plains and mountainous areas[16]. Under the Köppen scheme, Sardinia falls within the warm temperate zone with hot, dry summers (Fig. 14, letter Csa). In practical terms, the mean temperature of the coldest months sits between −3°C and 18°C, the warmest months exceed an average of 23 °C, and typical annual precipitation ranges from about 380 to 760 mm. Climatically, the island mirrors the broader Mediterranean pattern: generally mild conditions with marked diurnal and seasonal swings. The year is structured around a hot, dry spell that peaks in July and August, a cooler, wetter season from December to March, and transitional periods in between. Most winds and rainfall are concentrated in the wet season[17]. These gradients matter for settlement form because they modulate exposure to sun, wind, and humidity and, in turn, influence how compactness, orientation, open space, and building mass are combined in vernacular fabrics.
Across Sardinia, several Mediterranean morphological features and bioclimatic characteristics of vernacular architecture reappear in different configurations, reflecting geomorphological diversity and associated climatic variants (Figs. 23 and 24). According to the Köppen classification, the Sardinian climate can be divided into four sub-climates: sub-tropical (the warmest, along the coastal zones), hot temperate (in the lowland areas), sub-littoral (in the hilly regions and plateaus), and sub-continental (the coldest, in the mountainous areas)[18], as shown in Fig. 25. This section uses these categories as a framework to explain recurrent relationships between climate, topography, and settlement morphology.
In southern lowland settlements, the courtyard-house fabric is typically compact and inward-oriented. Narrow, wall-bounded lanes serve domestic units organised within perimeter enclosures, where the patio and shaded transitional spaces, including loggias (Fig. 26), support ventilation control, solar protection, and productive microclimates associated with enclosed gardens[19]. Building layouts are often arranged to manage solar exposure, while thick earthen walls (Fig. 27), commonly around 40 cm, provide thermal mass that moderates daily temperature swings[20]. Timber intermediate floors and pitched roofs with lightweight structural systems and tiled coverings are recurrent, reflecting both material availability and the need to balance summer

16 More precisely hills occupy about 67.9 % of the territory, plains account for roughly 18.5 %, and mountains for the remaining 13.6 %.
17 Desogus *et al.* 2016, p. 575.
18 *Ibidem.*
19 Sanna 2009b, p. 103.
20 Desogus *et al.* 2016, p. 575.

**Fig. 23**
*Map of rural building archetypes in Sardinia, following the 1950s classification of Osvaldo Baldacci. Source: Direzione Regionale per i beni culturali e paesaggistici della Sardegna 2005, p. 17*

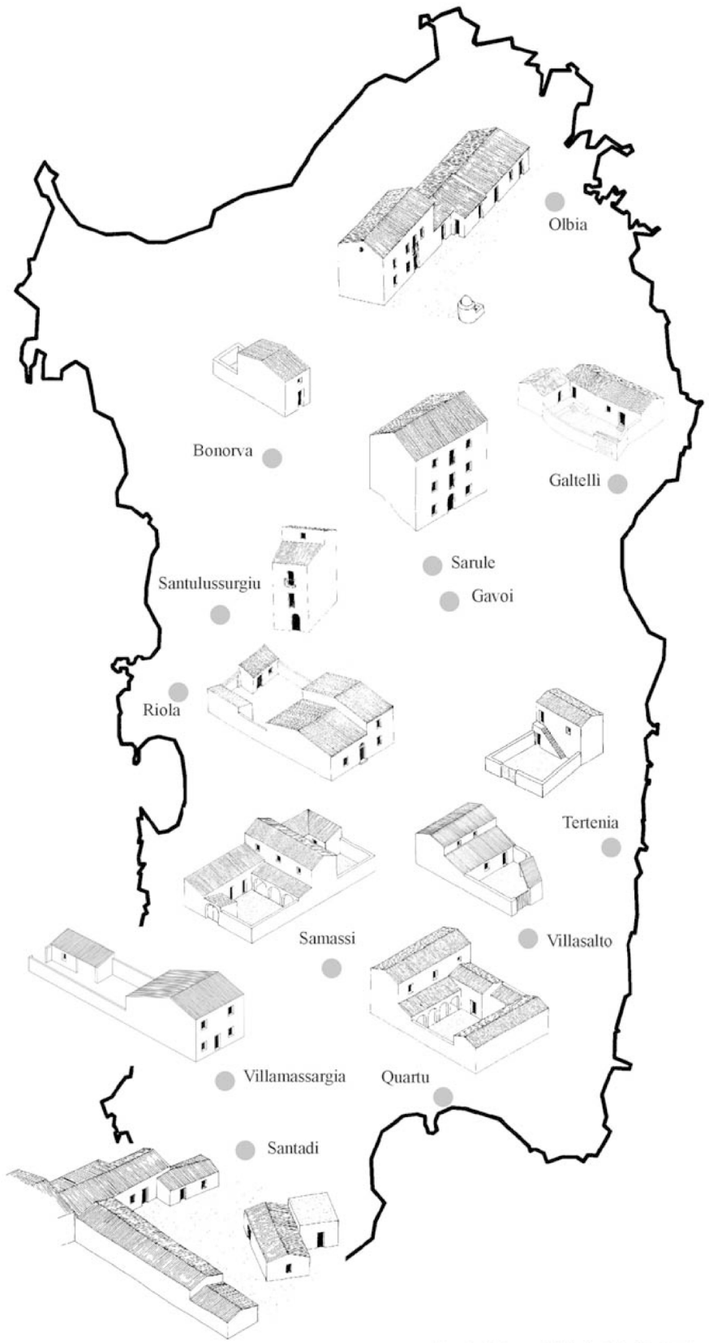
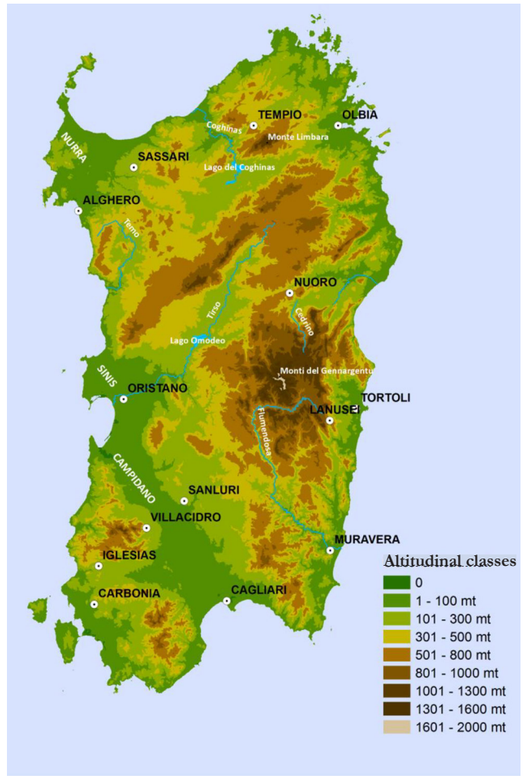


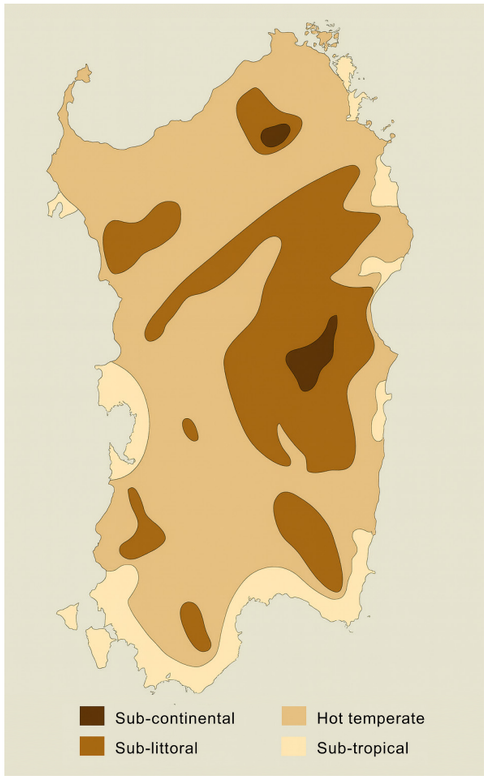

**Fig. 24 (next page, left)**
*Physical map of Sardinia with altitudinal classes. Source: ISPRA 2015, p. 6.*

**Fig. 25 (next page, right)**
*Map of Sardinia with Köppen-Geiger climate variants classification. Source: Desogus et al. 2016, p. 579.*








heat mitigation with winter protection. In these fabrics, outdoor sociability is frequently structured around the courtyard as a hinge between household life and community relations.

By contrast, many northern centres privilege a more outward-facing relationship with public space. The so-called "elementary house" aligns along primary routes and frames the street and square as key social and climatic spaces (Fig. 28). Where private open space is limited, shading devices and seasonal vegetation can play a central bioclimatic role. Vines, for instance, are often positioned on façades above entrances to filter summer sun while allowing winter radiation (Fig. 29). Parcels frequently align along matrix thoroughfares, and the continuity of elevations with ordered openings reinforces a strong street edge that supports both movement and everyday interaction.

In mountainous areas, topography becomes a dominant driver of form. Building cells operate within terraced structures (Fig. 30), and incremental accretion produces compact, multi-storey houses that stack volumes to reduce exposed surface area and manage winter conditions[21]. Service and

21 Sanna 2009b, p. 103.



**Fig. 26 (above)**
*Traditional loggia in a typical house of the Sardinian flatlands in Casa Baldussi, Settimo San Pietro (Metropolitan Area of Cagliari), Sardinia. Source: photo by Alice Agus, 2024.*



**Fig. 27 (below)**
*Adobe wall, locally called ladiri in Serrenti (SU), Sardinia. Source: photo by Alice Agus, 2018.*







**Fig. 28 (above)**
*A winding street in Villasalto (SU), Sardinia. Source: 377project.com*



**Fig. 29 (below)**
*Stone wall revealed after the fall of the plaster in Nuragus (SU), Sardinia. Source: author's photo.*



**Fig. 30**
*The compact settlement of Orani (NU), Sardinia. The houses follow the topography. Source: author's photo.*

animal spaces are typically located at ground level, with living quarters above, and, where historically present, modest south-facing timber balconies supported solar access and use. Construction shifts towards substantial stone walls, reflecting material availability at altitude and the need for durability and thermal stability. Related compact house types with fewer storeys and small rear enclosures are also found in northern hills and tablelands, adapting the same logic to gentler terrain. Finally, isolated farmsteads in more recently colonised territories often develop through modular accretions that may culminate in court-like organisations, while remaining distinct in their enclosure systems and mixed use of earthen brick and stone[22].

These matrices rarely occur in pure form. Transitional belts often show hybridisation and recombination, as in the irregular courtyard fabrics of the Marmilla or the persistence of courtyard-house types along the edges of the Barbagie. The Campidano of Oristano is exemplary in this respect: an intermediate landscape where outward-oriented courtyard houses with rear courts negotiate a permeable threshold between private and public space, and where internal spatial elements such as the sala help mediate between street-facing sociability and the climatic advantages of sheltered open space. For the purposes of this thesis, these morphological variations are read as operational evidence of how settlement structure and building typologies encode environmental adaptation, and they provide a basis for interpreting vulnerabilities and feasible intervention strategies in different Sardinian contexts[23].

22 Desogus *et al.* 2016, p. 575.

23 Sanna 2009b, p. 111. To go deeper into the thematic see: Baldassarre 1843; Baldacci 1952; Sanna 2009b; Giannattasio 2021.





## 2.2 From Post-War Development Pressures and Landscape Deterioration to a New Environmental Awareness in Architectural and Urban Culture

Since the aftermath of the Second World War, culminating in the years of rapid economic expansion during the 1960s, the Italian building sector experienced an uncontrolled boom, marked by low construction quality and indiscriminate land consumption[24]. Between 1951 and 1971 alone, the national housing stock increased by more than 26 million rooms[25]. Urban expansion in this period raised pressing social concerns, which initially often overshadowed environmental ones[26]. As discussed in the previous chapter, the State proved unable to guide territorial transformation effectively in response to the needs of existing communities and landscapes[27]. Instead, it relied heavily on land consumption and private-sector building production[28]. Urban sprawl entailed the extensive consumption, occupation, and progressive transformation of land, primarily through the uncontrolled expansion of low-density residential areas. This process was closely linked to the widespread adoption of private cars, which enabled access to city centres even from more distant locations near the countryside[29]. At the same time, the acceleration of State-led industrialisation reinforced a development paradigm in which productive capacity and consumer growth emerged as the principal indicators of welfare and modernisation[30]. As a result, artificial surfaces have increasingly replaced agricultural land, pastures, and natural areas, increasing negative effects such as higher greenhouse gas emissions, higher infrastructure costs for transport, water and electrical power, and the degradation of the ecosystem services[31]. Within this framework, historic centres, whether in large cities or in smaller settlements, have progressively lost their traditional residential and

24 Desogus 2018, p. 5; Vitiello 2012, p. 16.

25 Vittorini *et al.* 1978, pp. 29-30.

26 Guardigli 2018, p. 21.

27 Brenna 2013.

28 Romano *et al.* 2020.

29 Marta 2010, p. 74.

30 Vitiello 2012, p. 16.

31 Millennium Ecosystem Assessment 2005. "*Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling*". Ecosystem services comprehend provisioning services (material products obtained by ecosystems, such as food and water); regulating services (benefits deriving from the regulation of natural processes such as air quality, pollination, and climate regulation); cultural services (immaterial benefits such as aesthetical and spiritual values, education, and cultural identity); supporting services (base processes that allow the others to be possible such as photosynthesis, habitats for biodiversity and soil formation).



**Fig. 31**
*Unauthorized construction activity on the coasts of Sicily. Source: qds.it*

**Fig. 32 (next page)**
*Culverted canal in Assemini (SU), Sardinia. Source: Autonomous Region of Sardinia, p. 9.*

social functions[32]. One of the European regions most affected by this process is Southern Italy, particularly its coastal areas[33] (Fig. 31).
Urban sprawl was only one manifestation of the broader disregard that post-war urban development showed for the environmental characteristics of the territory. Geomorphological and hydrographic conditions were frequently disregarded, leading to interventions such as the diversion or culverting of rivers, building on flood-prone areas, and construction on geologically unsuitable soils. Such practices increased exposure to catastrophic events such as floods and landslides, as well as modified and altered natural ecosystems[34]. One of the most emblematic cases of these actions is the 1966 landslide in Agrigento in Sicily, where the speculative construction of entire neighbourhoods on clay slopes, already known for their instability, caused the collapse of several buildings and triggered a national debate that led to the first attempts at reforming urban planning legislation[35].
In Sardinia, the culverting or enclosure of canals and rivers within underground concrete structures became widespread, redirecting watercourses to avoid

32 Vittorini *et al.* 1978, pp. 30-36.

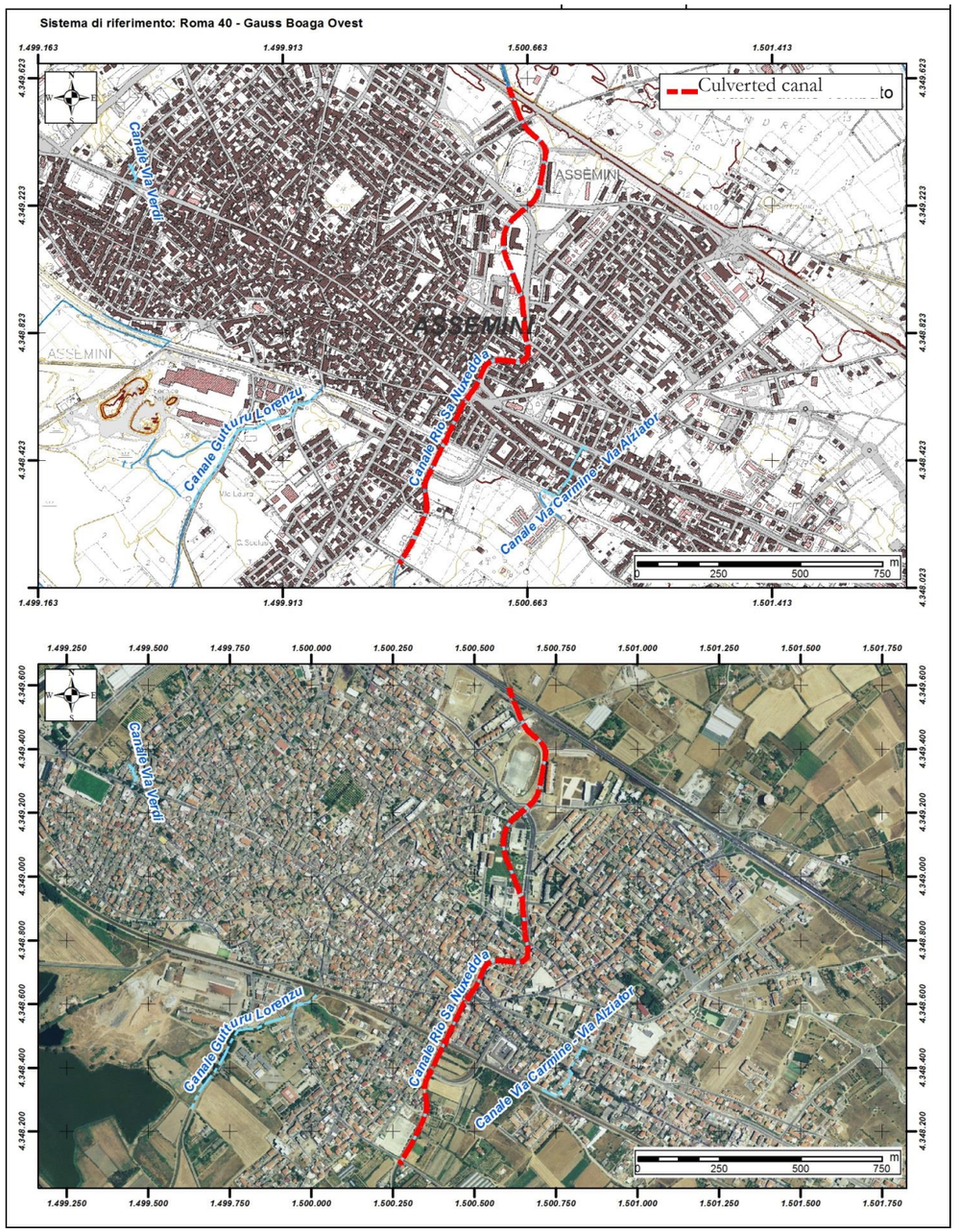
33 Romano *et al.* 2016; Fiorini *et al.* 2017.

34 Surian, Rinaldi 2003, p. 108; Ridolfi *et al.* 2025, p. 198.

35 Italian Camber of Deputies 2022, pp. 129, 135, 150. The document brings together parliamentary debates, official records, parliamentary questions, technical reports, and acts relating to the Agrigento landslide.







obstructing land colonisation and territorial development[36] (Fig. 32). In villages such as Bitti, the network of culverted rivers and channels running beneath streets and squares aggravated the effects of extreme flood events[37]. In parallel, in the Italian historic settlements, typologies and spatial dimensions were often misaligned with contemporary standards, as well as weakened by wartime damage. Moreover, mostly in Southern Italy, many historic dwellings gradually became sites of overcrowding. These challenges were exacerbated by widespread poverty, which fuelled the phenomenon of "self-building" practices. New buildings and expansions were erected with readily available, low-cost materials and frequently in violation of regulations, functioning as an adaptive response to the shortcomings of the system. In many towns and villages, dense networks of social relations facilitated the proliferation of these "informal" dwellings. Such networks operated through reciprocal exchanges of labour, skills, and mutual support, thereby reducing construction costs and overcoming institutional and market constraints. As a result, these housing solutions were more responsive to actual needs, in terms of cost, timing, and flexibility, than those which could be provided by either the State or the formal building sector[38]. The scale of the phenomenon is exemplified in Sardinia: a 1986 regional survey recorded 60,000 unauthorised dwellings, accounting for nearly 30% of total housing production over the previous fifteen years[39].

At the level of architectural design, the formal and technological innovations of contemporary architecture progressively came into conflict with energy and environmental issues. Experimentation with new spaces for industrial production and work often produced buildings with poor environmental performance[40]. Meanwhile, advances in structural engineering gradually released the building envelope from its static functions, reducing it to a lightweight membrane (Fig. 33). This transformation granted greater formal and architectural freedom but simultaneously undermined the envelope's role in regulating the indoor microclimate. As a consequence, reliance on artificial climate control became not only unavoidable but also a central element in both design strategies and the everyday use of space. Thus, architects were granted a new form of design freedom, often celebrated as "innovative", which, despite its apparent advantages, was increasingly detached from the specific conditions of place and climate, and became heavily dependent on mechanical systems of environmental control[41].

As Reyner Banham observed:

36 Autonomous Region of Sardinia 2021b. The lists contains the known culverted or enclosed canals and rivers.

37 ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale 2013, p. 27.

38 Cremaschi 1990, pp. 139-142.

39 *Ivi*, p. 140.

40 Guardigli 2018, p. 22.

41 Zaffagnini 1993, p. 7; Fathy 1986, p. 5.





"*For anyone who is prepared to foot the consequent bill for power consumed, it is now possible to live in almost any type or form of house one likes to name in any region of the world that takes the fancy*"[42].

Technological advances improved indoor thermo-hygrometric comfort and public health, introducing new standards in healthcare and environmental well-being[43]. These standards, substantially different from those embedded in historic architecture, fostered new expectations among users and increased pressure for historic buildings to adapt to evolving demands, a pressure that continues to shape energy-efficiency regulation[44]. At the same time, significant challenges emerged in integrating modern building services into historic structures, raising questions of compatibility across technical, cultural, landscape, and conservation dimensions[45].

From the 1960s onwards, Italian intellectual discourse began to critically reassess the concept of environment, prompted by growing awareness of the adverse impacts of consumerism and the uncontrolled exploitation of natural resources. This shift paralleled an international debate and drew strength from an expanded understanding of ecology that progressively moved beyond the natural sciences to encompass human-made systems and inhabited environments[46]. Within this horizon, the holistic insight that "*all things hang together*" supported what would later be framed as 'systems thinking'[47]. As Meadows explained, a system is "*a set of things—people, cells, molecules, or whatever—interconnected in such a way that they produce their own pattern of behavior over time*"[48]. A key implication is that outcomes cannot be understood by isolating single variables, because patterns of behaviour emerge from interdependencies, structures, and feedbacks[49].

In planning, this perspective encouraged cross-fertilisation between ecological and urban reasoning. Holling and Goldberg, for instance, argued in 1971 that urban systems share core features with ecological systems: both are shaped by historical contingencies, spatial linkages, and non-linear dynamics, and both exhibit a degree of persistence within a range of conditions[50]. They also warned that interventions that disturb complex balances can yield unexpected

42 Banham 1969, p. 187.

43 Guardigli 2018, p. 20.

44 Lucchi, Pracchi 2013, p. 17.

45 e.g. Buda *et al.* 2021.

46 Vitiello 2012, p. 17; Osman 2022, p. 232. Initially defined in the late nineteenth century as the study of interactions between living organisms and their surroundings, ecology evolved until no longer confining itself to natural ecosystems alone, becoming a complex organic body of knowledge aimed at studying the relationships between living organisms and the environment in which they interact.

47 *Ivi*, pp. 17-18.

48 Meadows 2008, p. 2.

49 Meadows 2008.

50 Holling, Goldberg 1971, p. 221, 225.

**Fig. 33**
*Curtain wall, Pirelli Skyscraper, built in 1956. Milan, Lombardy. Source: fondazionepirelli.org*



outcomes, calling for "*new principles based more on recognition of our ignorance than presumption of our knowledge*"[51] when acting upon systems we only partially understand.

Two years later, Holling (1973) developed the concept of resilience in ecological systems, distinguishing it from stability. Rather than describing rapid return to a single equilibrium, resilience refers to the capacity of a system to absorb disturbance and still maintain key relationships and functions, acknowledging that complex systems may persist across multiple states[52]. The concept of resilience soon resonated beyond ecology, laying the foundation for what would later be called urban resilience[53]. In this sense, the ecological framing of resilience began to inform how scholars and practitioners would later discuss a city's capacity to endure shocks and long-term stresses, including climate-related events, resource constraints, and social disruptions, without losing essential functions[54].

Within architectural and planning culture, ecological consciousness supported new approaches during the 1960s and 1970s. Ian McHarg's Design with Nature (1969) proposed methods for guiding settlement according to ecological suitability, using layered surveys to align development with environmental capacity[55]. McHarg's approach also resonates with earlier traditions of survey-based regional planning associated with Patrick Geddes, who argued for "survey before plan" and approached cities as living organisms linked to geographic and cultural context[56]. In this lineage, planning depends on careful knowledge of local conditions and community life before intervention.

Comparable holistic concerns were also articulated in Italy. Gustavo Giovannoni's "*ambientista*" approach insisted on relating new architecture to the existing urban fabric and its wider setting[57]; later, Roberto Pane's "*istanza*

51 *Ivi*, p. 221.
52 Holling 1973, p. 17.
53 e.g. Vale, Campanella 2005.
54 Ribeiro, Gonçalves 2019.
55 McHarg 1971.
56 Geddes 1915.
57 Giovannoni 1929, p. 188; Stabile 2017, p. 136.







**Fig. 34**
*New Barrid Village, Kharga, Egypt by Egyptian architect Hassan Fathy, known for developing a modern architecture that would reflect the environmental and social principles of the traditional one. Source: photo by Viola Bertini.*

*ecologica*" foregrounded systemic interrelations between built heritage and environment within preservation culture[58]. These strands indicate that the systems-oriented ethos was not confined to a single national context, even where the vocabulary differed.

Around the same period, further theoretical positions developed. Banham's reinterpretation of architecture as an environmental control system placed technical performance and mechanical services at the centre of modern design[59]. This view highlighted both the potentials and pitfalls of this approach: while it offered unprecedented freedom to design regardless of site or climate, it also foreshadowed a deepening dependence on energy consumption and mechanical services in architecture.

In contrast, other thinkers reacted against the alienation of late-modern architecture from its context. Rudofsky and Norberg-Schulz, for example, looked to vernacular traditions and lived meanings of space, seeking lessons in spontaneous, climate-responsive building cultures[60]. In Italy, Eduardo Vittoria warned against an ideology of unlimited environmental transformability, where technology was pursued as an end in itself and risked producing irreversible environmental and cultural degradation[61].

In response, climate-attentive design approaches sought to reframe the relation between architecture and environment. The Olgyay brothers developed bioclimatic design as a method for aligning building form, orientation, and envelope with local climate, reducing dependence on mechanical systems and external energy inputs[62]. Alongside bioclimatic design, a profusion of related concepts entered the architectural vocabulary (bio-architecture, eco-friendly architecture, bioecology, etc.), all signifying a growing awareness of ecological principles in design practice[63]. In built practice, Hassan Fathy is often referenced for translating vernacular climatic logics and earthen techniques

58 Pane 1978a; Pane 1978b.
59 Banham 1969; Banham 1971.
60 Rudofsky 1964; Norberg-Schulz 2006; Guardigli 2018, p. 32.
61 Vittoria 1973; Desogus 2018, p. 7.
62 Olgyay 1981; Guardigli 2018, p. 33.
63 Guardigli 2018, p. 40.

into an explicit architectural agenda, offering a concrete example of this environmentally oriented shift[64] (Fig. 34). From the mid 1970s, particularly in the wake of energy shocks, these concerns increasingly consolidated into approaches later associated with sustainable or "green" architecture, emphasising context, climate, and resource efficiency[65].
The 1973 energy crisis further accelerated ecological awareness by revealing the vulnerability of fossil-fuel dependence and prompting a rethinking of environmental and urban policies[66]. In this context, modern architecture was challenged both to revalue local context and identity and to reduce resource consumption by prioritising territorially available resources[67].
Within this context of change, the notion of heritage underwent a significant broadening, as already outlined in the previous chapter, encompassing both architecture and nature within the unified concept of environment and landscape. This shift was the outcome of a long-standing cultural debate which, since the 1930s, had focused on the harmony between environmental context, architectural design, and urban form[68]. It was reinforced by key European and international documents, including the 1972 European Soil Charter[69], the UNESCO World Heritage Convention of the same year[70], and the 1975 European Charter of the Architectural Heritage[71]. This expanded conception of heritage also acquired an explicitly ethical dimension, linking landscape to memory, identity, and intergenerational responsibility[72].
As Salvatore Settis states:

"*the lesson of ancient landscapes* […] *teaches us that the opposition between nature and culture must be reconsidered in terms of continuity between the two poles, and that between architecture and landscape there can be a calculated harmony*; […] *that architecture should neither be conceived nor experienced solely under the shadow of aesthetic principles, but enlightened by a strong ethical concern oriented toward the common good*"[73].

64 Fathy 1986.

65 Bassas *et al.* 2020.

66 Wolfson 2013.

67 Guardigli 2018, p. 33.

68 Vitiello 2012, pp. 23-24.

69 Council of Europe 1972. This charter includes soil among the resources to be protected and preserved.

70 UNESCO 1972. This convention establishes the definition of natural and cultural heritage and outlines the guidelines for its protection addressed to the Member States.

71 Council of Europe 1975. The charter explicitly states that architectural heritage cannot be separated from its environmental and natural context, and that they must be regarded as inseparable elements, subject to unified protection.

72 Hartog 2007, pp. 188-189.

73 Settis 2017, p. 58





## 2.3 Heritage as a Non-Renewable Resource and the Concept of Sustainability

The concept of sustainable development, defined by the Brundtland Report (1987) as development that "*meets the needs of the present without compromising the ability of future generations to meet their own needs*"[74], has clear parallels with long-standing principles of heritage conservation. Over a century earlier, John Ruskin framed a similar ethic of stewardship by arguing that "*the earth is an entail, not a possession*"[75]. In this sense, cultural heritage can be understood as a finite and non-renewable resource: once historic fabric, settlements, or material evidence are lost, they cannot be meaningfully replaced. As an irreproducible record of material culture, each historic structure or urban ensemble embodies values accumulated over time and anchored to its specific context[76]. Walter Benjamin's well-known argument about the "*here and now*" of the work of art captures this point by stressing that authenticity is inseparable from situated existence and material continuity[77].
This convergence between sustainability and conservation has also gained formal policy recognition. In 2014, the Council of the European Union explicitly framed cultural heritage, in all its forms, as "*a strategic resource for a sustainable Europe*"[78], while acknowledging the challenges posed by contemporary environmental, social, economic, and technological change[79].
At the national scale, Italy has long enshrined the protection of landscape and cultural heritage as a fundamental duty of the Republic in Article 9 of the Constitution, amended in 2022 to include the protection of the environment, biodiversity, and ecosystems "*also in the interest of future generations*"[80]. Conceptually, therefore, sustainability and conservation share an intergenerational horizon and a duty of care towards irreplaceable common goods, whether natural or cultural.
However, these conceptual convergences did not automatically translate into integrated operational frameworks. For much of the late twentieth century, sustainability agendas in the building sector and heritage policy developed largely in parallel, with only limited overlap. A gradual shift emerged when culture began to be articulated as a core component of sustainable development, creating a clearer basis for linking conservation, urban regeneration, and environmental goals. The next section outlines this transition and its main policy milestones.

74 United Nations 1987, chapter 3, point 27.

75 Ruskin 1903, p. 232. Original text published in 1849.

76 Vitiello 2012, . 83.

77 Benjamin 2008, p. 21.

78 Council of Europe 2014, paragraph 2.

79 *Ivi*, paragraph 4.

80 Italian Government 1948, art. 9.

### 2.3.1 The "Fourth Pillar" of Culture: Convergences Between Conservation and Sustainability

The modern sustainability paradigm emerged in the 1970s and 1980s from environmental concerns and climate risks, gradually institutionalising also economic, and social dimensions[81]. Foundational frameworks such as Agenda 21 (1992) advanced sustainable planning and construction by encouraging life cycle approaches to materials, renewable energy uptake, and reductions in resource consumption, while also recognising the building sector as both a major source of impacts and a key arena for experimentation[82]. This link remains decisive today, as buildings and construction still account for a substantial share of global energy and process related emissions[83]. In the years that followed, this global commitment was translated into binding agreements. A crucial milestone was the Kyoto Protocol (1997, entered into force in 2005), the first international framework to set differentiated targets for industrialised nations and to reinforce the role of renewable energy in climate action[84]. The Kyoto Protocol, together with the UN Habitat II Conference on human settlements[85], framed explicit commitments for applying sustainability principles to the built environment. By the late 1990s and early 2000s, this impetus was reflected in several European cities through the experimentation of low energy, low impact districts, often characterised by extensive reliance on solar energy[86].

Yet cultural heritage was rarely cited as part of this equation, until the late 20th century, when a conceptual shift was underway. Policymakers and scholars began to articulate culture as the "fourth pillar" of sustainable development, alongside economic growth, social inclusion, and environmental balance. Key milestones illustrate this integration. UNESCO's World Conference on Cultural Policies (1982)[87] and the report Our Creative Diversity (1996)[88] argued that cultural diversity and heritage are central to human development,

81 Between the 1970s and 1980s, consequently to the scientific advances of the 1950s and 1960s in atmospheric measurements, the publishing of some robust reports on greenhouse gas (e.g., Charney Report, 1979) first established the causal link between anthropogenic emissions and global warming. From this moment on, the risks linked to climate change was further investigated and disseminated by entities such as the Intergovernmental Panel on Climate Change (IPCC), supporting actions and measures within international governance.

82 United Nations 1992a, chapter 7, section G; Guardigli 2018, p. 34.

83 UNEP - United Nations Environment Programme 2024.

84 United Nations 1997.

85 United Nations 1996.

86 The pilot projects for sustainable urban development were carried out in Freiburg (the Vauban district), Stuttgart, and Linz's "Solar City". They were characterised by low-energy residential buildings, bio-architecture, and advanced systems for harnessing renewable energy.

87 UNESCO 1982. On that occasion, the first 'World Decade for Cultural Development' (1988–1997) was launched.

88 UNESCO 1996.





even if these ideas initially struggled to enter mainstream sustainability frameworks. A clearer turning point came in the early 2000s: UNESCO's Universal Declaration on Cultural Diversity (2001)[89], the Convention for the Safeguarding of Intangible Heritage (2003)[90] and the Convention on the Diversity of Cultural Expressions (2005)[91] reframed cultural diversity, tangible and intangible, as a common heritage of humanity and asserted that it is as necessary for humankind as biodiversity is for nature[92]. In parallel, Agenda 21 for Culture warned against the homogenising effects of globalisation, which can endanger cultural plurality in ways analogous to environmental degradation[93].

Within this evolving policy landscape, heritage conservation, including historic centres, gained stronger recognition as a component of sustainability. UNESCO's Recommendation on the Historic Urban Landscape (HUL) (2011) reconceived urban conservation not as resistance to change, but as a negotiated practice that integrates cultural specificities with the demands of contemporary urban life[94]. Rather than treating preservation as opposed to development, the HUL approach embeds heritage within sustainable urban planning, seeking a managed co-evolution of historic fabric and modern city life[95]. The notion of "integrated conservation" introduced by the 1975 European Charter of Amsterdam anticipated this approach by promoting the reuse of historic buildings, compatible new functions, and closer alignment between planning tools and heritage values[96].

Historic urban centres have also been discussed as practical models of sustainable urbanism[97]. Europe's historic city centres are traditionally compact, conserving land and energy, mixed-use, ensuring vibrancy, and walkable environments, qualities now championed as sustainable urbanism[98]. Furthermore, as the Aalborg Charter on sustainable cities emphasised in 1994, rehabilitation of underused or decaying historic urban areas channels development pressure into the existing city footprint, curbing urban sprawl and safeguarding the consumption of greenfield sites[99]. At the same time, land consumption in Italy has remained high despite limited demographic

89 UNESCO 2001.

90 UNESCO 2024. Original text published in 2003.

91 UNESCO 2005a.

92 UNESCO 2001, article 1.

93 UCLG - United Cities and Local Governments 2004, part I, paragraph 2.

94 UNESCO 2011; UNESCO 2019b.

95 Della Torre 1999.

96 Council of Europe 1975, points 7-9.

97 e.g. Marini et *al.* 2007.

98 Jacobs 1961; Lehmann 2016. Sustainable urbanism emphasises compact form, walkability, and mixed-use vitality. Jane Jacobs similarly argued that human-scaled diversity underpins urban life and its capacity to cope with change.

99 European Commission 1994, part I, point 8. The Charter emerged from the European Sustainable Cities campaign launched at the Aalborg Conference (24–27 May 1994), promoting Local Agenda 21, stakeholder engagement, and cooperation among local authorities.

growth[100], suggesting that demand for new development often reflects dissatisfaction with what already exists rather than a purely quantitative shortage[101]. In this context, improving the usability, performance, and liveability of historic areas, where feasible, can extend their service life and attractiveness, while reducing the perceived need to build anew.

Adaptive reuse[102], compatible retrofitting[103], and circular economy[104] approaches are widely discussed as promising integrated strategies, provided that they remain sensitive to heritage significance and local conditions[105]. For this reason, multidisciplinary approaches grounded in a thorough understanding of each site's values and constraints are crucial to negotiate trade offs between conservation, social equity, and environmental performance in specific projects. Despite this potential, implementation is frequently hindered by regulatory, technical, financial, and knowledge related barriers, summarised in Fig. 35. Although framed around adaptive reuse and retrofitting, these constraints are treated here as a proxy for implementation feasibility in historic settlements, since they also condition what can be delivered and maintained over time in marginal contexts[106].

Another critical aspect of sustainable historic centres concerns maintenance and durability. Routine works are typically low impact actions that extend service life and prevent minor defects from escalating into resource intensive failures or premature replacement[107]. In this light, conservation should be a planned process that coordinates all activities so each action contributes to the whole. This "planned conservation" integrates preventive measures with remedial works and adaptive reuse or retrofitting, aligning practices within a single management framework rather than as isolated interventions[108].

---

100 ISPRA 2024. Soil consumption continues to advance at the rate of approximately 20 hectares per day on Italian national territory.

101 Aliverti 2010, p. 5, in Pianezze 2012, p. 65; Bullen 2011, p. 1657.

102 Douglas 2006, p. 146. Adaptive reuse modifies an existing building for a different use, extending its service life.

103 UNEP – United Nations Environment Programme 2009. Building retrofitting upgrades existing buildings to improve performance while reducing energy demand and emissions.

104 A circular economy moves away from the linear "take-make-dispose" model by keeping products and materials in use for longer through maintenance, repair, refurbishment, repurposing, and recycling, thereby reducing waste and environmental impacts.

105 Conejos *et al.* 2012; Wade and Visscher 2021; European Environment Agency 2022; Armstrong *et al.* 2023.

106 These constraints are consistent with applied research on town-centre vacancy and low-carbon reuse within the TREBUChEt project (Heaphy *et al.* 2025), a policy and interview-based study combined with stakeholder engagement was used to identify recurring barriers to adaptive reuse and retrofit in small-town contexts

107 e.g. Hammond, Jones 2008. Embodied energy is the primary energy invested in materials prior to operation, from extraction and manufacturing to transport (and sometimes construction, maintenance, and end-of-life). Using this lens frames conservation as a whole-life, long-term strategy rather than a one-off intervention.

108 Della Torre 2023.





| Category | Adaptive Reuse | Retrofitting |
|---|---|---|
| Decision-making | Complexity in the decision-making process; conflicts of interest among stakeholders. | |
| Stakeholder Engagement | Lack of participatory decision-making and limited representation. | |
| Perception Mismatch | Perceived mismatch between the cost involved in building reuse and the results obtained. | |
| Data Limitations | | Limited availability of reliable information. |
| Regulatory | Wide gaps between suggested policy directives and the local contexts in which reuse strategies are implemented; and a lack of alignment between policies and their implementation strategies. | Strict conservation requirements limit retrofit measures for heritage buildings; lack of policy for life cycle impact assessment. |
| Technical | Complex integration of modern technologies; difficulty complying with codes, regulations and design requirements; rating tools often overlook the sustainability and carbon benefits of conserving existing buildings. | Lack of supportive tools for retrofit work; standard energy models inadequately represent heritage building construction, leading to ineffective retrofit approaches; specific characteristics of heritage buildings require consideration in retrofit processes. |
| Knowledge | Limited knowledge among decision-makers about the environmental benefits of adaptive reuse. | Limited understanding of retrofit definitions. |
| Capacity Constraints | Shortage of expertise and skills, especially in circular economy practices. | |
| Financial Constraints | High costs of labour and limited financing for adaptive reuse and retrofit projects; increasing costs of renovation and cost of financing. | |

**Fig. 35 (next page)**
*Barriers to adaptive reuse and retrofitting. The table was developed from a semi-systematic literature review conducted in Scopus and Google Scholar, in which relevant sources were screened for inclusion and the resulting evidence was synthesised into thematic categories of barriers, Source: author's elaboration based on TREBUChEt project outputs and final report (Heaphy et al. 2025), University College Dublin and University of Galway.*

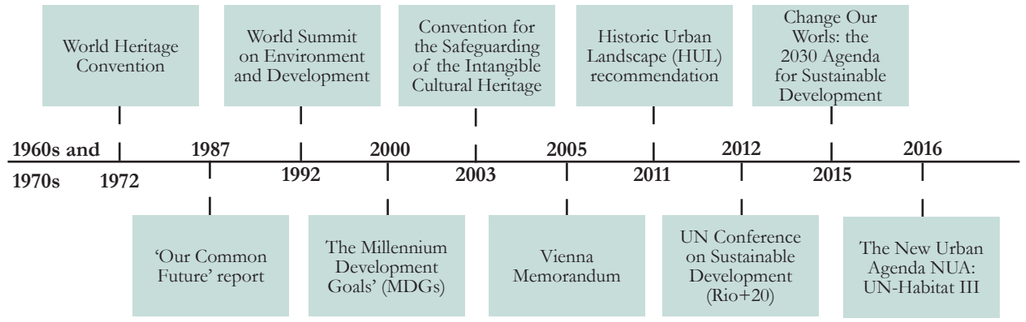
### 2.3.2 Integrating Cultural Heritage into Climate Action

As climate change reshapes urban and territorial priorities, conservation can be reframed as a pragmatic component of sustainability and risk management, especially in historic settlements where action must work with existing fabric rather than replace it. This shift is relevant to inner and marginal villages, where climate exposure intersects with demographic decline and limited administrative capacity, turning adaptation into a governance and prioritisation problem as much as a technical one.

At the level of global agendas, the 2030 Agenda frames a broad set of urban objectives under SDG 11, one of the 17 Sustainable Development Goals (SDGs) to address the main contemporary challenges before 2030[109], including risk reduction, resource efficiency, and more integrated approaches to planning across urban and rural areas[110]. Yet culture remains only weakly embedded in the SDG architecture. Cultural heritage is explicitly referenced mainly through Target 11.4[111], which calls for strengthened efforts to protect and safeguard the world's cultural and natural heritage[112]. Figure 36 situates SDG 11.4 within the broader sequence of UN and UNESCO policy milestones that progressively framed sustainability and urban agendas. This limited visibility has been noted by scholars who argue that culture, often described as a "fourth pillar" of sustainability, is not consistently translated into operational sustainability frameworks and indicators[113]. In response, heritage bodies have worked to make the connections more explicit, for instance by mapping how heritage can support multiple SDG targets and by framing heritage as an active resource for climate mitigation and adaptation rather than an aesthetic add-on[114].

For small settlements, this integration matters in concrete terms.

**Fig. 36**
*Timeline of key UN and UNESCO milestones framing sustainability and urban agendas, contextualising SDG 11.4.*
*Source: Author's review from El Faouri, Sibley 2024, p. 2.*




109 United Nations 2015b; United Nations 2025.
110 UNESCO 2019b.
111 United Nations 2015b.
112 El Faouri, Sibley 2024.
113 Duxbury *et al.* 2016.
114 ICOMOS 2020.





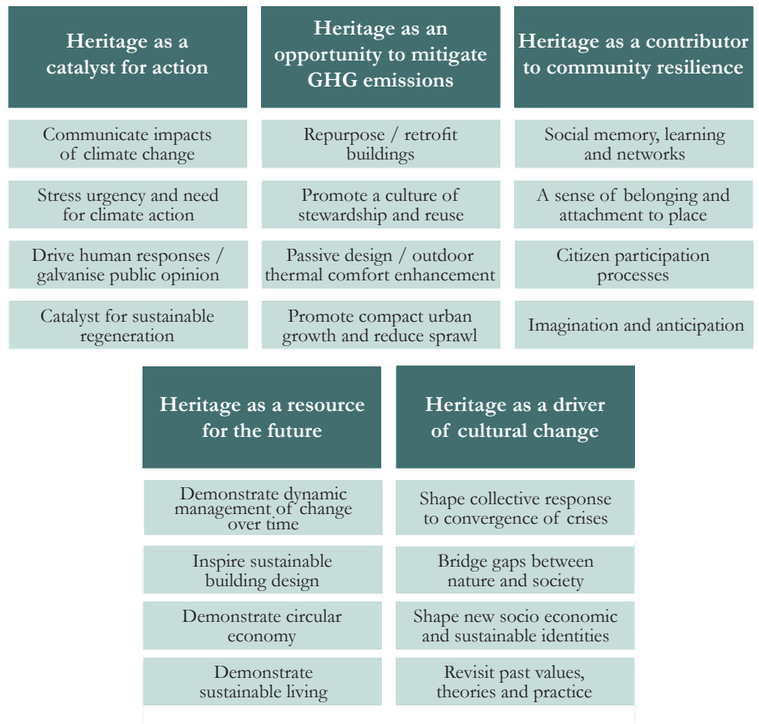



**Fig. 37**
*Synthesis of how heritage can contribute to climate action, used here as an interpretive frame for historic villages.*
*Source: Author's review from Crowe et al., 2023, p. 11.*

Climate impacts can magnify existing structural fragilities, including ageing infrastructure, underused building stock, and reduced continuity of everyday care. At the same time, historic villages and cultural landscapes often retain place-based knowledge embedded in settlement location, building typologies, and resource practices, which can inform contemporary adaptation when critically reinterpreted rather than idealised[115]. The point, therefore, is not to treat heritage as a nostalgic constraint, but to recognise it as a field of actionable assets and trade-offs, where climate action requires selective priorities, compatible technical solutions, and governance arrangements that match local capacities[116]. Figure 37 summarises these pathways and is used here as a synthesis frame for reading heritage as an operational resource that requires prioritisation and capacity-matched governance.

115 ICOMOS 2019.
116 Pultrone 2020, p. 984.

## 2.4 The Relevance of Community Involvement in Sustainable Development and Conservation Processes

Communities are increasingly framed as central actors in the stewardship of historic environments, not only because they inhabit heritage settings, but because everyday practices, attachments, and uses contribute to the meanings through which places become culturally significant over time. From this perspective, heritage significance is not a fixed attribute of fabric alone, but the outcome of ongoing social recognition and negotiation. International frameworks codify this shift towards a people-centred approach. The Council of Europe's Framework Convention on the Value of Cultural Heritage for Society (Faro Convention, 2005) treats cultural heritage as a resource for sustainable development and quality of life, and recognises the role of "heritage communities", whose members both benefit from heritage and share responsibility for its care, thereby linking participation to governance rather than to consultation alone[117].

In parallel, contemporary conservation theory emphasises that memory, identity, and social attachment are constitutive components of heritage value, which tends to be sustained when communities recognise themselves in places and are enabled to transmit such value through informed action[118]. At the same time, community involvement should not be idealised. Participation can be uneven, contested, and shaped by power asymmetries, limited time, and variable local capacity, particularly in marginal territories. For this reason, effective and legitimate heritage policy requires processes that treat communities as internal stakeholders in defining priorities and trade-offs, while also making explicit who participates, through which instruments, and with what decision-making weight. In operational terms, this supports approaches that combine technical assessment with locally grounded knowledge, strengthening place recognition and shared responsibility for long-term maintenance and change[119].

117 Council of Europe 2005, articles 1, 2 and 4. Under the Faro Convention, 'heritage communities' are groups of people who value particular aspects of cultural heritage and, within the framework of public action, seek to sustain and pass them on to future generations.

118 Sanna 2009, p. 10.

119 Ricoeur 2005; Kindon 2007; Magnaghi 2010; Cerutti 2019, p. 58.





### 2.4.1 Community Participation as an Integral Element of Heritage Care

If heritage is understood as a cultural process, co-produced with communities, participation is not an optional add-on to conservation but part of what makes care workable and legitimate[120]. The rationale is normative, instrumental, and social. Normatively, participation operationalises cultural rights by giving communities a structured role in defining significance, setting priorities, and discussing trade-offs, rather than treating heritage as a domain reserved to experts alone[121]. Instrumentally, participation can improve the fit of policies and projects to local conditions, because residents and users contribute situated knowledge about everyday practices, informal maintenance routines, seasonal uses, and perceived risks that are often invisible to formal surveys[122]. Socially, participation can strengthen the intangible conditions that support long-term stewardship after exceptional funding or external teams have left, including trust[123], reciprocity[124], and civic agency[125]. These benefits are most visible when participation moves beyond one-off hearings to capability-building[126] processes that equip people to deliberate, decide, and steward, in line with the people–places–policies approach advanced within the culture and development field[127].

At the same time, as already mentioned, participation should not be idealised. In marginal and rural contexts, it may be constrained by uneven representation, local conflicts, fatigue, and limited administrative capacity,

120 Waterton, Watson 2011, p. 3.

121 Council of Europe 2005. See: preamble; articles 1(a), 4, 5(a), 8(c), 11(b–e), and 12. Together they frame cultural heritage rights and their exercise through participation, require frameworks for joint action that include civil society alongside experts, and recognise the public interest in heritage.

122 Annunzi, Moruzzo 2006, p. 2.

123 Understood as the confidence that actors will share information honestly, keep commitments, and address problems transparently. This concept is implicit in the frameworks that ask for shared responsibilities and clear processes, e.g. Council of Europe 2005; UNESCO 2011.

124 Represents the "give-and-take" between stakeholders, the cooperation between public, private, and community to co-produce values through care, with an exchange of resources and responsibility. Examples of it within "enterprising communities" can be found in EURICSE – European Research Institute on Cooperative and Social Enterprises 2022.

125 The community's effective capacity to act, meaning the ability to frame issues, take decisions, access tools and budgets, and carry out agreed actions. It is supported by the documents that recognise the right to participate and capability of action, e.g. Council of Europe 2005, articles 1(a), 2(b) and 12.

126 Sen 1999; Pracchi, Oteri 2023, p. 200. The term capability-building derives from Amartya Sen's Capability Approach, which conceives development as the enhancement of people's substantive freedoms (their actual abilities to do and to be what they value) rather than as the mere provision of resources.

127 UCLG 2004; UNESCO 2016; UNESCO 2019a.

and it can be reduced to procedural compliance without any real redistribution of influence[128]. For this reason, the relevant question for this study is not whether participation is desirable in principle, but how it should be framed as a condition of feasibility for conservation interventions and long-term strategies in marginal contexts, where local capacity and maintenance realities shape what can endure over time.

People-centred approaches are reinforced by international and European instruments that link value recognition to inclusive procedures and shared responsibility, from cultural rights frameworks to conventions and charters that encourage public involvement in environmental and heritage decision-making[129]. The Faro Convention is particularly relevant here because it frames participation not only as consultation, but as shared responsibility for heritage as a resource for society, thereby pointing towards governance arrangements that can endure beyond one-off projects[130].

In practice, engagement can take different forms across the project life cycle, from statutory consultation to co-design workshops for adaptive reuse, community mapping and oral history initiatives to surface intangible values, and stewardship agreements for the care of spaces and minor heritage. When participation is organised as capability-building rather than as a single event, it can generate practical benefits: *ex ante*, it can reveal weaknesses and constraints early enough to adjust design and reduce delays; during delivery, it can provide structured feedback that improves usability and acceptance; *ex post*, it can support evaluation not only of outputs but also of learning effects and local ownership[131].

However, there is a persistent implementation gap. Participation in heritage and planning often remains tokenistic, especially when processes are designed to legitimise pre-defined choices rather than to structure genuine deliberation[132]. Evidence from Sardinia has highlighted this risk in relation to planning and regeneration programmes for historic centres, where physical improvements have not consistently translated into broader social and economic vitality, and where accessibility outcomes have been uneven across resident groups[133].

128 de Luca *et al.* 2021, p. 2.

129 Cultural participation is affirmed as a right in the Universal Declaration of Human Rights (UN General Assembly 1948, Art. 27). In heritage and landscape governance, participation is embedded in the Burra Charter (Australia ICOMOS 1999), the Vienna Memorandum (UNESCO 2005b), the Québec Declaration (ICOMOS and UNESCO World Heritage Centre 2008), and the European Landscape Convention (Council of Europe 2000; ratified by Italy in 2006).

130 Council of Europe 2005. Ratified by Italy in 2020.

131 Annunzi, Moruzzo 2006, pp. 2-3.

132 Leach *et al.*, 1997; Masika, Joekes 1997, pp. 15-16.

133 See Autonomous Region of Sardinia 2013b, pp. 317–322; Leone and Zoppi 2016b; and the University of Cagliari evaluation of the socio-territorial effects of policies under Regional Law No. 29/1998 (2012), which reports improved physical quality but weaker social and economic impacts, and notes citizens' stated willingness for a more active role.





These findings suggest that participation, if weakly designed, may accompany investment without improving the conditions that sustain long-term use and care. Against this backdrop, local experiments have attempted to combine conservation rules with adaptive, community-facing methods. For instance, experiences linked to detailed planning have tested participatory pathways and flexible interpretative approaches intended to reconcile typological continuity with contemporary needs[134]. Such cases are relevant as methodological signals: they indicate that the effectiveness of participation depends on its integration with regulatory instruments, incentives, and technical guidance, rather than on deliberation alone.

Participation becomes particularly consequential where structural constraints are present, notably the recurring mismatch between public safeguarding responsibilities and predominantly private ownership of the built fabric, combined with complex procedures and limited municipal capacity. This can produce a governance gap in which institutions retain authorising power but lack operational means for everyday care, while owners bear costs and constraints with limited support[135]. In these conditions, structured community partnerships can function as connective tissue, supplementing scarce capacity through third-sector actors, civic groups, and knowledge institutions, provided that roles, responsibilities, and resources are clearly specified[136]. Evidence from crisis situations also suggests that, when institutional and market mechanisms falter, communities may self-organise to maintain services and places, including heritage assets, but these efforts tend to endure only when they are supported by enabling instruments, resources, and technical guidance[137].

Recent Italian experiments in commons-oriented governance of cultural heritage suggest that collaboration pacts, advisory bodies, and co-managed projects can help translate participation into shared responsibility[138]. Their relevance lies less in their replicability as "models", and more in the way they clarify an operational point: participation contributes to feasibility when it is linked to instruments that allocate tasks, enable maintenance, and stabilise commitments over time.

134 One example is Mogoro, see Atzeni et al. 2022: the DPHC was developed as a "test" case combining participatory pathways with an adaptive interpretative approach, allowing more flexible readings of volumetric constraints when traditional techniques and local materials were retained, in order to reconcile typological continuity with contemporary needs.

135 Colavitti, Serra 2017, p. 83.

136 Žuvela *et al.* 2023, pp. 6868-6870.

137 Euricse 2022, p. 8.

138 On commons-oriented Participatory Governance of Cultural Heritage (PGCH) in Italy and related tools (collaboration pacts, co-managed arrangements), see Iaione et al. 2022; examples include Co-Roma, the Royal Estate of Carditello Foundation, and the La Paranza cooperative in Naples.

### 2.4.2 Community Resilience and Participation in Sustainable Development Processes

From a theoretical perspective, the relevance of community participation to sustainable development has been recognised for decades, and it entered global policy language in an explicit way with the 1992 Earth Summit and Agenda 21, which emphasised local capacity-building and community-driven pathways to sustainability[139]. Although participation is formally recognised as a mechanism linking heritage and sustainability within international heritage regulations, most global policy documents provide little conceptual clarification of the term and rarely articulate how participatory practices concretely contribute to Sustainable Development Goals[140]. Recent scholarship has tried to address this gap by framing participation through distinct "roles" (Fig. 38), which are useful here as an analytical lens[141]: participation as a right[142] (linked to social sustainability and cultural justice), as a driver (supporting governance quality, resource stewardship, and local vitality), and as an enabler (sustaining long-term commitment and adaptive change)[143]. Importantly, these roles are not automatically realised: they depend on facilitation, institutional openness, time, and the availability of minimal organisational capacity[144].

European policy streams increasingly treat participation as a strategic resource, particularly where sustainability goals intersect with territorial cohesion and rural development. Instruments such as Community-Led Local Development and the LEADER approach provide a relevant precedent because they do not only "encourage" engagement but also assign Local Action Groups formal responsibilities and dedicated budgets[145]. Across programming periods, this has enabled small-scale projects for village renewal, public space improvement, cultural and environmental enhancement, and local services, while offering a procedural frame for co-design and local priority-setting. At the same time, evaluations of LEADER highlight limits that matter for marginal territories: decision making can be dominated by local authorities, procedures may lack transparency and be vulnerable to conflicts of interest, and only a minority of Local Action Groups demonstrate innovation or cross sector integration[146].

More recent initiatives, such as the New European Bauhaus (NEB), further reinforce community involvement by linking climate action with social

139 United Nations 1992a, chapters 7, 28, and 37.
140 Rosetti *et al.* 2022, p. 3
141 *Ibidem*.
142 Settis 2017.
143 Rosetti *et al.* 2020.
144 Rosetti *et al.* 2022.
145 European Network for Rural Development n.d.
146 European Court of Auditors 2010.





inclusion and lived quality[147]. The NEB's emphasis on consultation, networking, and pilot projects is relevant to this study mainly as a reminder that sustainability transitions increasingly demand social legitimacy and co-production, not only technical optimisation[148]. Flagship projects such as Barcelona's Superilla illustrate how participatory processes can support the reallocation of space and the improvement of comfort and public health[149]. Yet such cases come from resource-rich metropolitan contexts and should be treated as illustrative rather than as models transferable to small, capacity-constrained settlements.

Participation has also become particularly visible in the clean energy transition, where governance innovations have been institutionalised in EU frameworks[150]. Renewable Energy Communities (RECs) are defined as legal entities enabling citizens, local authorities, and SMEs to produce, consume, store, share, and sell renewable energy through open and voluntary participation, with community benefit rather than profit as the primary purpose[151]. This framing treats energy transition not only as infrastructure deployment, but as a participatory institution with distributional implications, including access for low-income and vulnerable households[152]. In practice, cooperative experiences, such as Som Energia in Spain, have combined collective generation with social solidarity mechanisms and educational programmes[153]. Empirical research also indicates that when communities are involved early in decisions about the siting and design of renewable installations, outcomes tend to be perceived as fairer and more acceptable, because local health, environmental, and economic concerns are addressed upfront[154]. Community empowerment in energy matters is also strongly reflected in enhancing lifestyle. This includes a desire to be self-sufficient and promote a sense of community as citizens want to become more independent from fossil fuels and from centralised energy supply[155]. For marginal contexts, the key point is again operational: participatory governance can improve legitimacy and reduce conflict, but only if it is supported by enabling conditions and does not shift excessive burdens onto communities with limited time and capacity.

These debates connect directly with the concept of community resilience, which becomes especially relevant in periods of transition and in places facing demographic decline and economic stagnation. In social systems, resilience is commonly understood as the capacity to absorb disturbance, reorganise, and continue to function while undergoing change, retaining core identity,

147 Rosado-García *et al.* 2021.
148 Rosado-García *et al.* 2021, p. 6.
149 European Union 2023.
150 Popescu *et al.* 2022, p. 3.
151 European Union 2018, article 2, paragraph 16.
152 *Ivi*, article 18, paragraph 1.
153 European Commission 2020, p. 22.
154 e.g. Gross 2007.
155 European Commission 2020, p. 22.

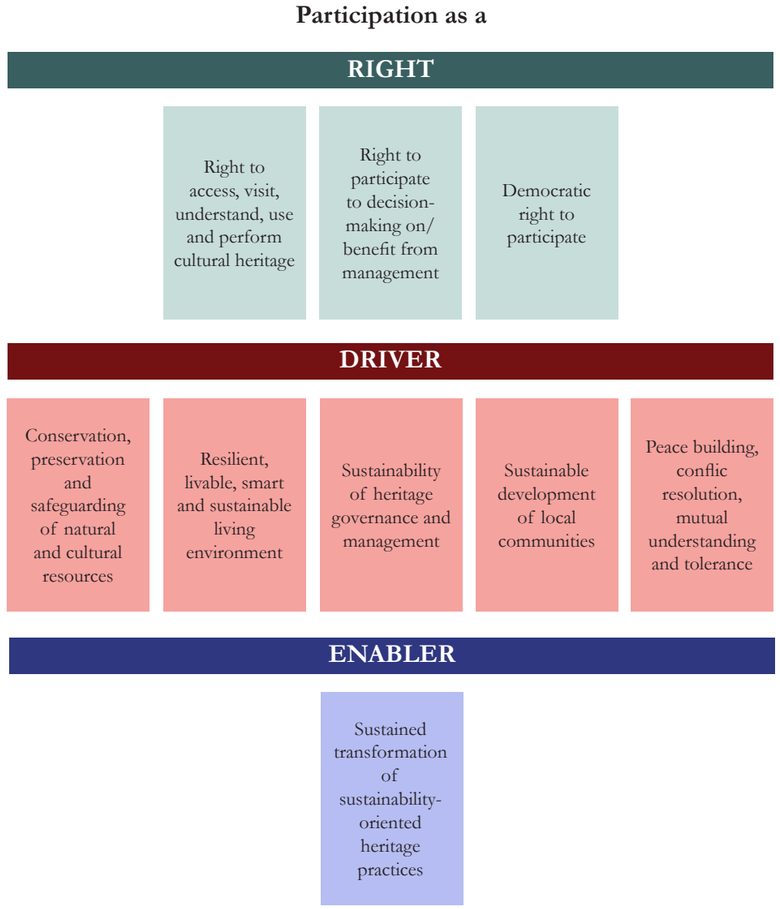



**Fig. 38 (above)**
*Coding of roles of participation and subcategories. Source: Author's graphic elaboration from Rosetti et al. 2022, p. 3.*

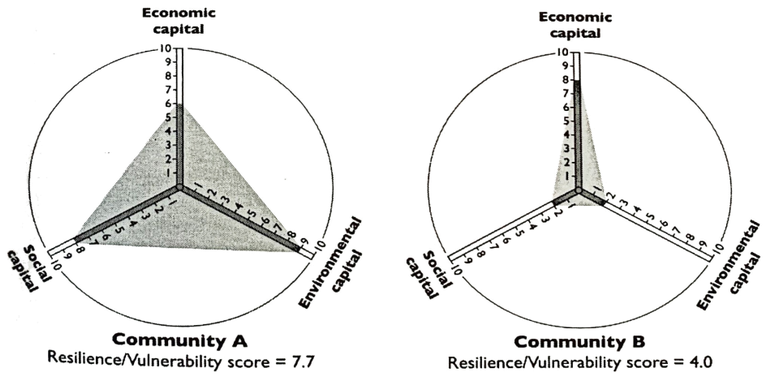



**Fig. 39 (below)**
*Hypothetical example of two case study communities with high (left) and low (right) resilience scores based on quantification of social, economic, and environmental capital. Source: Wilson 2012, p. 49.*





feedbacks, and structures over the relevant time horizon[156]. Communities have agency: they can learn, coordinate, and deliberately transform practices when conditions require it. In this view, resilience is both an outcome and a process linked to social learning, institutional adaptation, and the willingness to assume responsibility for shared development pathways[157]. The literature often frames resilience through multiple "capitals" (Fig. 39): economic capital (income, funding access, viable enterprises, infrastructure), social capital (bonding, bridging, and linking ties to institutions), and environmental capital (healthy ecosystems and the long-term balance between settlement and landscape)[158]. For historic villages, the practical implication is not that participation "solves" marginality, but that well-designed engagement can help stabilise the social and institutional conditions that make conservation feasible, especially where routine maintenance, stewardship, and service provision depend on fragile local capacities. In other words, participation contributes to resilience when it is linked to durable arrangements that allocate responsibilities, enable maintenance, and support adaptive capacity over time, rather than being treated as a one-off consultation exercise[159].

This chapter has framed historic settlements as socio-environmental systems, showing how climatic logics embedded in traditional fabrics and evolving sustainability agendas shift conservation beyond aesthetics towards performance, risk, equity, and long-term management. It also stresses why feasibility matters in marginal contexts, where demographic decline and limited institutional capacity condition what can be delivered and sustained. Against this backdrop, climate action and energy policy place historic architecture under pressure to demonstrate improvement through metrics designed for standard building stocks, encouraging either exclusion from upgrading or replacement to meet minimum thresholds. This makes clear the need for approaches grounded in knowledge building, significance, and context-specific option appraisal rather than fixed targets. Chapter 3 consolidates these external drivers and interpretative frameworks, clarifying the pressures, assumptions, and recurring tensions that condition how sustainability is pursued in heritage settings.

156 Walker *et al.* 2004, p. 2.
157 *Ivi*, p. 19.
158 *Ivi*, p. 22.
159 *Ivi*, p. 1-3.

# Chapter 3.
# Historic Architecture and Contemporary Environmental Challenges: Theoretical Approaches, Policies, and Operational Models

In current times, historic architecture sits at the intersection of rising environmental pressures, changing social expectations, and increasingly demanding regulation in response to the climate emergency. The Mediterranean is already experiencing compounded climate hazards, and heritage urban contexts face concentrated exposure that tests both material fabric and the social practices that sustain it. These conditions are no longer speculative, as assessments identify the Mediterranean as a climate hotspot and heritage research documents growing risks for historic settlements and ensembles.

In this context, policy is accelerating, requiring national renovation planning, minimum energy performance provisions, and a phased transition towards zero-emission buildings. Yet the instruments used to deliver these goals have largely been developed for standard building stocks and quantitative compliance pathways. In heritage contexts this has often led to two problematic outcomes: exemptions that leave significant portions of historic stock outside improvement trajectories, or interventions shaped by minimum thresholds that can favour replacement over fabric-conscious upgrading. Both tendencies make it difficult to balance climate action with conservation aims.

More recently, European and national guidance has advanced frameworks that couple significance-led conservation with performance improvement, beginning with knowledge building and option appraisal rather than fixed targets. These instruments help establish a shared vocabulary, but they also expose the limits of one-size-fits-all metrics. At the same time, sustainability discourse in the built environment has not always translated into context-sensitive practice and is sometimes used in ways that obscure trade-offs and responsibilities.

This chapter delineates the contemporary challenges that heritage faces in relation to climate change, energy transition, and landscape protection. It provides a focused synthesis of the climatic context, the evolving legislative framework, and the operational models and debates that shape current practice, in order to clarify pressures, assumptions, and recurring tensions.





## 3.1 The Effects of Climate Change in the Mediterranean Area and the Region of Sardinia

The Mediterranean is widely recognised as a climate change hotspot, where multiple hazards converge on territories with high exposure and vulnerability across densely settled coasts, fragile inner areas, and culturally rich landscapes[1]. Over the twentieth century, the region experienced substantial warming alongside measurable shifts in precipitation patterns[2]. Projections for the twenty-first century indicate that these trends will intensify, with continued warming and a marked reduction in rainfall across most Mediterranean regions[3] (Fig. 40). Warming is expected in all seasons, but it will be stronger in summer than in winter and more pronounced over land than over the sea[4]. According to the IPCC AR6, Mediterranean warming is projected to outpace the global mean, with annual temperatures rising about 20% above the global average and summer increases up to 50% higher[5]. These trajectories are expected to increase the frequency, intensity, and duration of heatwaves. At the same time, precipitation is projected to decline across most sub-regions by

1 Giorgi 2006; Lionello *et al.* 2006; Giorgi, Lionello 2008.
2 Lionello *et al.* 2012; Ulbrich *et al.* 2012; Ulbrich *et al.* 2013.
3 Collins *et al.* 2013; Gualdi *et al.* 2013; Ulbrich *et al.* 2013.
4 Giorgi, Lionello 2008; Déqué *et al.* 2012.
5 IPCC 2022, p. 2237.

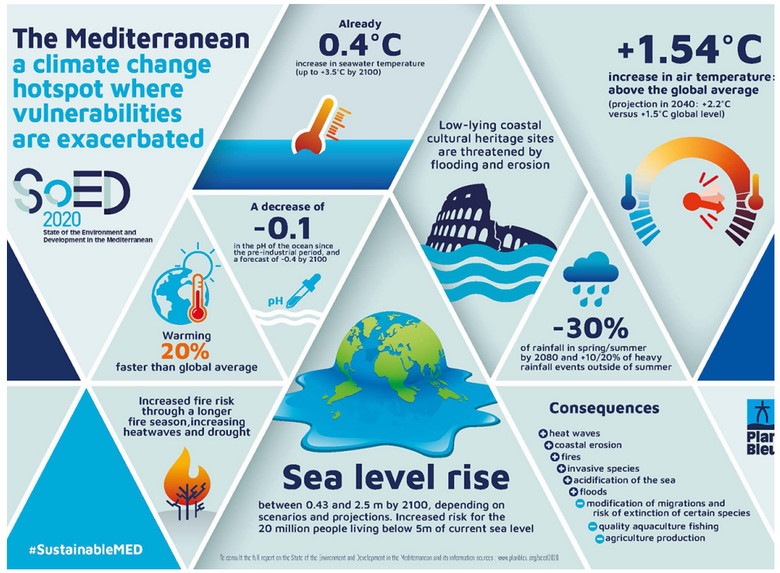



**Fig. 40**
*Main climate change effects on the Mediterranean region. Source: UNEP 2021.*

4 to 22%, depending on the emissions scenario[6]. Reduced rainfall, combined with increasingly arid conditions, would enhance evapotranspiration and heighten the risk of critical water shortages, particularly in the southern and eastern Mediterranean where water resources are already under severe stress[7]. The most severe drying is expected across Iberia, southern Italy, the southern Balkans, and Anatolia, amplifying climatic and ecological imbalances across the basin[8].

At the same time, daily minimum temperature has increased faster than daily maximum temperature, contributing to a growing incidence of tropical nights, when temperatures remain above 20 °C[9]. Tropical nights have notable implications for human health, particularly among vulnerable groups, and they also affect ecosystems, agriculture, and energy demand. Their rising frequency represents an important public health issue because it contributes to discomfort and heat-related illness linked to inadequate night-time recovery. Warm nights are often preceded by hot days, limiting the body's ability to recover from daytime thermal stress and increasing the likelihood of heat-induced distress[10]. Climate modelling synthesised by the European Environment Agency shows that this phenomenon is intensifying across Europe and that its latitudinal range is expected to extend further north in the coming decades (Fig. 41).

Although some hazards may appear less responsive when assessed through global-scale indices of extremes, Mediterranean-focused analyses confirm that extremes must be considered explicitly. In practice, it is often peak events, superimposed on deteriorating mean conditions, that drive the largest damages and test adaptation limits. Heatwaves, intense rainfall, and drought can have impacts that exceed what average changes alone would suggest, shaping ecosystems, economies, and societies in disproportionate ways. For this reason, hotspot mapping that combines mean changes with indicators of extremes can help prioritise support, improving the targeting of finance and the sequencing of measures over time[11]. Recent work complements traditional indices based on average temperature and precipitation by incorporating metrics on extremes such as heat, heavy precipitation, and dryness[12]. Approaches such as the Mediterranean Hotspot Index (MED-HOT) integrate changes in

6 IPCC 2014, pp. 8-9; IPCC 2022, p. 2235. The IPCC scenarios RCP 4.5 and RCP 8.5 represent two greenhouse gas concentration pathways used to project future climate conditions: RCP 4.5 assumes stabilisation of radiative forcing at 4.5 W/m² by 2100 through mitigation measures, while RCP 8.5 depicts a high-emission trajectory with radiative forcing reaching 8.5 W/m² by 2100.

7 Iglesias *et al.* 2007; García-Ruiz *et al.* 2011.

8 Lionello, Scarascia 2018, p. 1485.

9 Davy *et al.* 2017; Wang *et al.* 2017.

10 Hajat *et al.* 2002; Yavaşlı, Erlat 2018; Royé *et al.* 2021.

11 Lazoglou *et al.* 2024, pp. 1-2.

12 e.g. Giorgi, Lionello 2008. The Regional Climate Change Index (RCCI), which has long identified the Mediterranean basin as highly responsive.





extreme maximum and minimum temperatures, the upper tail of precipitation, and consecutive dry days to map sub-areas where hazards cluster and adaptive capacity is limited. These studies show that parts of southern Italy fall among the most sensitive zones, where decreasing annual and cool-season rainfall coexists with more frequent heavy downpours and flash-flood risk[13] (Fig. 42).

These climatic shifts do not act in isolation. They compound with urbanisation, land-use change, and biodiversity loss, generating cascading risks for ecosystems, economies, and cultural assets[14]. Water scarcity is projected to intensify as river low flows and annual runoff decline, reducing hydropower potential and increasing the likelihood of conflicts over water use among agriculture, urban areas, and ecosystems, with consequences for water availability and ecosystem functioning. Heat stress is expected to rise, particularly in urban areas, affecting energy demand, equity, and public health, while fire risk is projected to expand geographically and seasonally. In agriculture, rain-fed yields could decline steeply in vulnerable locations. Fisheries face adverse responses to ocean warming and acidification, while tourism may experience reduced summer climatic comfort, with potential shifts in seasonality and the spatial distribution of demand[15].

Cultural heritage concentrates these compound risks in particularly acute form. The Mediterranean basin hosts an exceptional concentration of cultural sites, including historic cities and settlements. According to UNESCO, nearly 60% of World Heritage cities in the region already report at least one climate hazard, and around 20% report three or more, with flooding most common in north-central and north-western sub-regions, while heat and drought dominate elsewhere[16]. By the end of the century, under a high-emissions scenario, more than half of heritage cities are projected to face at least two concurrent threats, while sea-level rise is expected to intensify risks for coastal sites through erosion and inundation. The trajectory points to greater severity and compounding of hazards, with flooding, drought, and heat acting in sequence to accelerate material decay and destabilise vulnerable foundations. The consequences are not limited to physical fabric. Damage to monuments and historic ensembles can undermine the practices and livelihoods that animate heritage places, including the transmission of traditional knowledge and craft, the continuity of cultural identity, and the community's capacity to steward its heritage. Displacement or disruption linked to water and food stress can further weaken continuity of use, which is critical for living heritage, and can erode social cohesion at the very moment when collective capacity is most needed for adaptation[17].

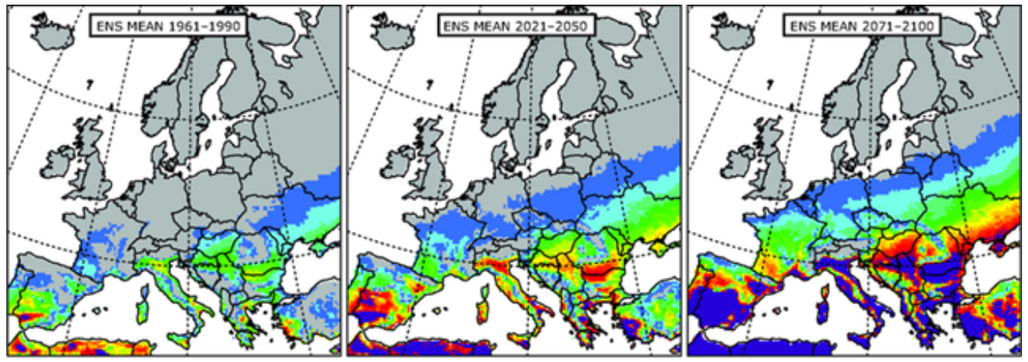
13 Lazoglou *et al.* 2024, pp. 3-6.

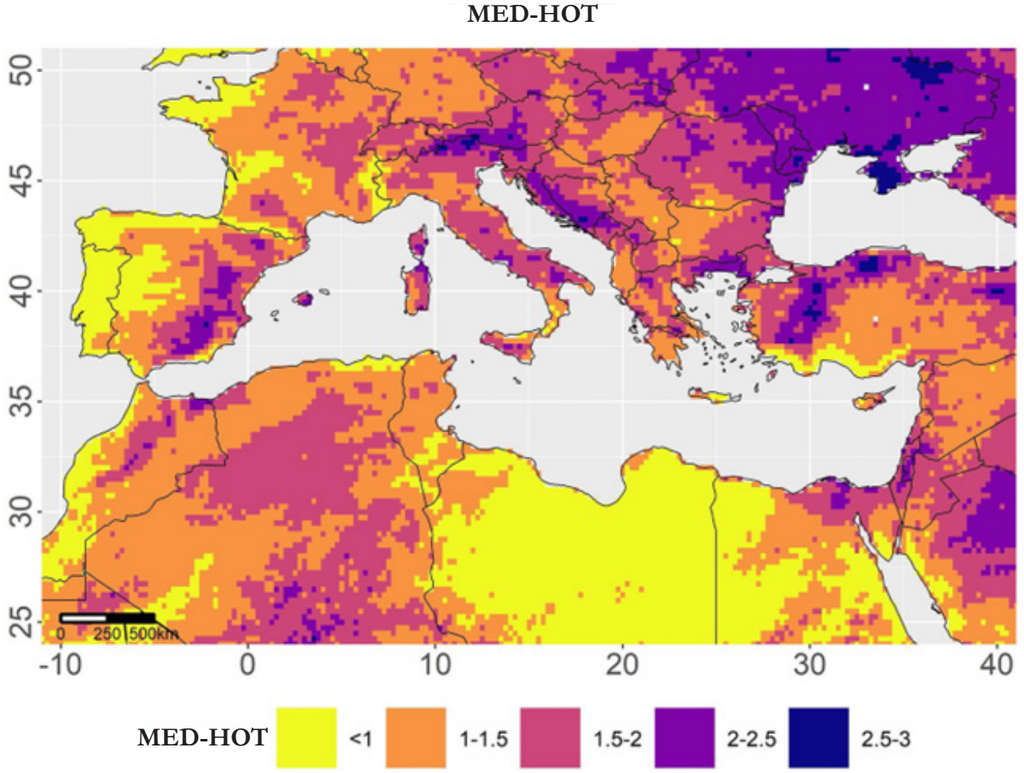
14 IPCC 2022, p. 2235.

15 *Ivi*, pp. 2242-2243.

16 UNESCO 2025, p. 10.

17 *Ivi*, pp. 51-52.







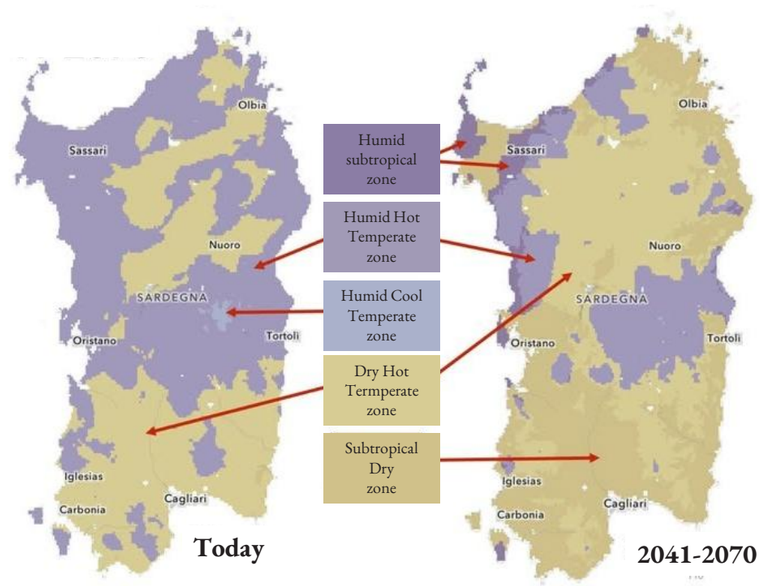




**Fig. 41 (previous page, above)**
*Map obtained by climate modelling, representing the number of combined tropical nights (T > 20°C) and hot days (T > 35°C) for different periods of time. Source: European Environment Agency 2012.*

**Fig. 42 (previous page, below)**
*Spatial variability of MED-HOT index classes in the Mediterranean region. Source: Lazoglou et al. 2024, p. 4.*

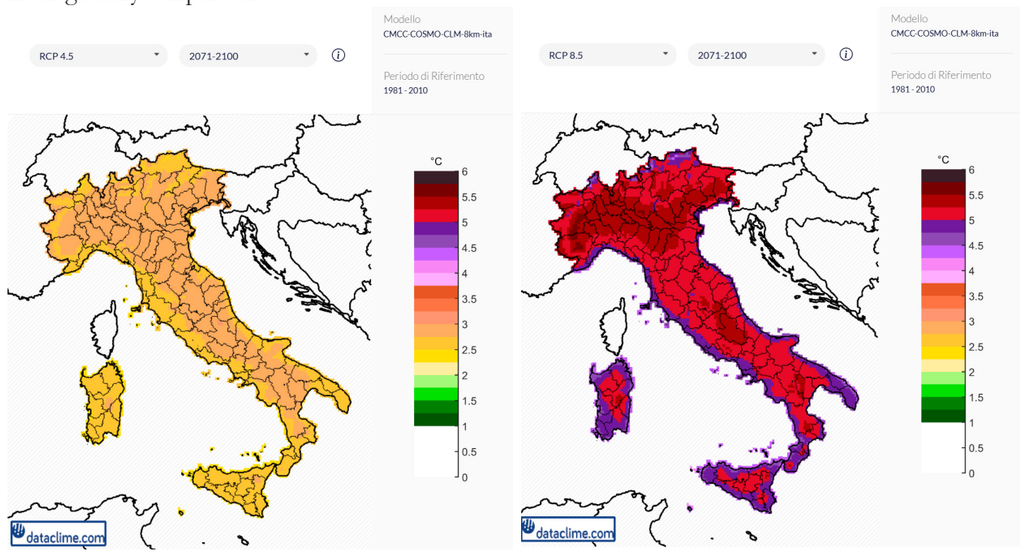
**Fig. 43**
*Sub-climatic zones in Sardinia, current situation and 2041-2070 situation. Source: Graphic elaboration from CHELSA data - Climatologies at high resolution for the earth's land surface areas*

Sardinia offers a telling case within this wider picture. Located at the centre of the Mediterranean, it exhibits both the general characteristics of the hotspot and distinctive local patterns (Fig. 43). Long-term records indicate that after a variable twentieth century, the island entered a consistent warm phase around 1990, with maximum temperatures remaining above the 1971 to 2000 climatic average[18]. Projections indicate a continued increase in mean temperatures, ranging from 2 °C to 3.5 °C for 2041 to 2070 and from 2.5 °C to 5.5 °C for 2071 to 2100, depending on the scenario (Fig. 44). They also show a rise in extremes, a decline in annual precipitation, and an increasing frequency of meteorological extremes, particularly heatwaves that lead to drought conditions and high-intensity rainfall events following prolonged dry spells (Fig. 44). In territories already exposed to hydrogeological hazards, these dynamics increase flood risk (Fig. 45) and tighten hydrological constraints, while raising wildfire risk and stressing ecosystems, agriculture, infrastructure, and settlements[19]. The Regional Adaptation Strategy (Strategia Regionale di Adattamento ai Cambiamenti Climatici, SRACC) acknowledges that impacts are unevenly distributed and mediated by local vulnerability and adaptive capacity. It calls for granular assessment, involvement of local administrations, stakeholder engagement, and chain-of-impact analyses across strategic sectors. It also recognises significant limits in current capacity, underlining the need to identify the determinants of these limits and to

18 Cuevas-Wizner *et al.* 2024, p. 6.

19 Autonomous Region of Sardinia 2024a, p. 16.

Average daily temperature




Consecutive days without rain

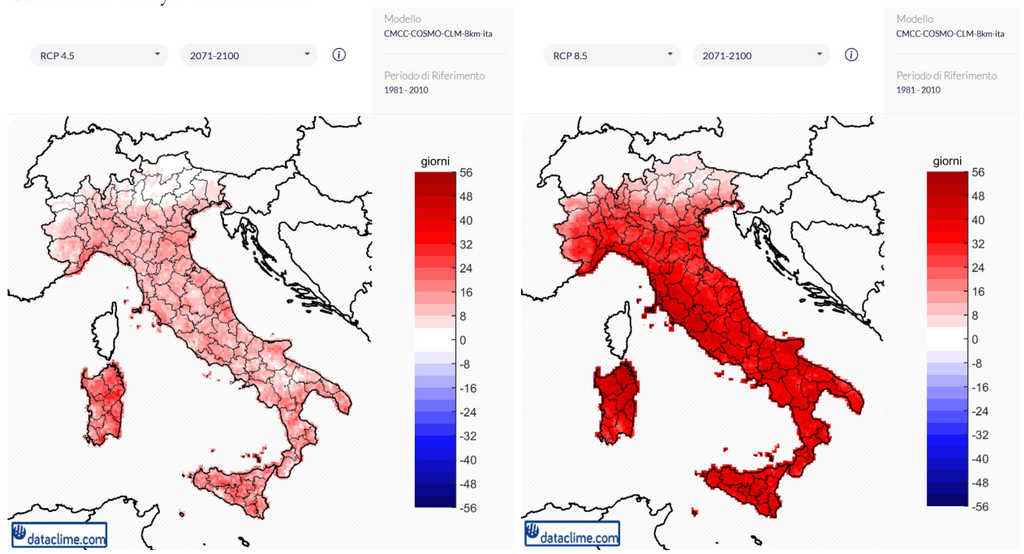









**Fig. 44 (previous page)**
*Climatic scenarios for Italy. Maps representing different variables in the low emissions scenario (RCP 4.5) and high emissions scenario (RCP 8.5). Source: CMCC.it*

**Fig. 45**
*Flood in Bitti (NU), Sardinia, November 2020. Source: ogginuoro.it*

empower key actors to reduce vulnerability and diversify response strategies as impacts intensify[20].

For heritage, the implications are concrete. Longer, hotter dry seasons accelerate stone weathering, salt crystallisation, and biological colonisation in archaeological sites and historic masonry, while short, intense downpours and flash floods threaten stability through erosion and moisture ingress. Coastal heritage faces the combined pressure of marine storms, shoreline retreat, and gradual sea-level rise, which over time may challenge even robust protection works. Intangible heritage is also exposed as agro-pastoral calendars slip out of alignment with climate conditions, water becomes less predictable, and younger generations migrate in search of opportunity, weakening the social continuity that sustains craft and know-how. These risks are not inevitable outcomes, but they are credible trajectories in the absence of proactive, place-specific adaptation that treats heritage as both a beneficiary of climate action and a contributor to it[21]. In this respect, Sardinia is illustrative of wider Mediterranean dynamics, where multi-hazard exposure intersects with development constraints and makes it essential to plan risk management and the conservation of cultural landscapes together. The evidence that southern Italy falls among the sub-regions where mean and extreme indicators signal vulnerability provides a quantitative basis for prioritising measures before critical thresholds in systems and heritage are crossed[22].

Bringing these strands together, the immediate challenge is to embed climate literacy across planning and conservation practice, to reinforce local functions that buffer extremes, and to sustain the knowledge systems that have enabled communities to live with climatic variability over centuries[23].

20 *Ivi*, pp. 22, 35-39.

21 UNESCO 2025, p. 54.

22 Lionello, Scarascia 2018; Lazoglou *et al.* 2024.

23 Ledda *et al.* 2020.

## 3.2 European and Italian Legislation Towards More Sustainable Urban Environments

The building sector plays a central role in global energy consumption and greenhouse gas emissions. For this reason, reducing energy use in buildings has been a long-standing priority within the European legislative framework. Since the late 1980s and early 1990s, EU directives have progressively addressed building energy performance, pursuing emissions reductions while also supporting technological innovation and wider socio-economic objectives[24].

### 3.2.1 European and Italian Regulatory Evolution

A first turning point in European regulation was Directive 2002/91/EC on the energy performance of buildings. It introduced key elements that still structure EU policy in this field, including a common methodology for calculating energy performance, minimum requirements for new buildings and major renovations, energy performance certification, and the inspection of technical systems. For heritage contexts, it also allowed Member States to exempt officially protected buildings and monuments where compliance would unacceptably alter their character or appearance[25].
This clause was confirmed and clarified in the recast Directive 2010/31/EU, which simultaneously raised the level of ambition by introducing nearly zero-energy buildings (nZEB)[26] and by strengthening the link between major renovations and mandatory energy upgrading through minimum performance requirements[27]. Italy transposed this framework through Legislative Decree 192/2005 and Legislative Decree 311/2006, establishing national rules on energy performance in buildings while reiterating that cultural heritage and buildings in historic areas could be excluded from minimum requirements when these would entail unacceptable alterations[28]. The implementing regulation in Presidential Decree 59/2009 followed the same approach[29], and Law 90/2013 updated the framework to align with Directive 2010/31/EU while improving certification and control procedures[30].

24 Lucchi, Pianezze 2013, p. 11.

25 European Union 2002, article 4, paragraph 3.

26 An nZEB is a building with very low annual energy demand, achieved through a high-performance envelope and efficient building services, with most remaining needs covered by renewables produced on site or nearby.

27 European Union 2010.

28 Italian Government 2005, article 3, paragraph 3, letter a, modified by Italian Government 2006b.

29 Italian Government 2009.

30 Italian Government 2013b.





Directive 2012/27/EU on energy efficiency extended the policy horizon by requiring Member States to develop long-term renovation strategies for the national building stock and to renovate annually 3 per cent of the total floor area of buildings owned and occupied by central government, or to adopt equivalent alternative measures. Exemptions for officially protected buildings remained[31]. However, as the regulatory agenda increasingly relied on standardised benchmarks and compliance pathways developed for new constructions, the application of energy requirements to existing buildings, and particularly to protected ones, often exposed a structural mismatch. Where methods, tools, and documentation were not adapted to traditional construction and heritage significance, procedures could encourage component-led solutions and replacement practices driven by minimum thresholds, rather than whole-building, fabric-conscious improvement[32].
The European Green Deal (2019)[33] and the Renovation Wave (2020)[34] marked a political acceleration, linking the 2050 climate-neutrality objective to a sharp increase in renovation rates[35]. The Renovation Wave called for doubling annual renovation rates and upgrading 35 million buildings by 2030, identifying as priorities the renovation of public buildings, the upgrade of the worst-performing stock including situations linked to energy poverty[36], and the decarbonisation of heating and cooling[37]. In countries with a large historic building stock, such as Italy, a significant share of priority buildings dates from earlier construction periods, which often coincide with traditional fabrics and conservation constraints (Fig. 46).
The recast Energy Performance of Buildings Directive (EPBD), Directive (EU) 2024/1275, confirms zero-emission requirements for new public buildings from 2028 and for all new buildings from 2030, while maintaining the possibility of exemptions for officially protected buildings where compliance would unacceptably alter character or appearance, or where renovation is not technically or economically feasible[38].
A central shift, however, lies in governance. Exemptions are now embedded within National Building Renovation Plans (NBRPs), which set time-bound trajectories and policies for renovating residential and non-residential stocks and specify how minimum performance requirements, financing, skills, and

31 European Commission 2012a.

32 Lucchi, Pianezze 2013, p. 17.

33 European Commission n.d.c.

34 European Commission n.d.d.

35 Council of the European Union 2019.

36 Bouzarovski, Petrova 2015. Energy poverty is a situation where a household cannot secure adequate energy services at an affordable cost. It can lead to under-heating or under-cooling, restricted use of appliances, or payment arrears. It usually stems from a combination of low income, high energy prices, and inefficient or poor-quality housing.

37 Council of the European Union 2020; European Commission 2020a.

38 European Commission 2024, article 9, paragraph 6, letter a.

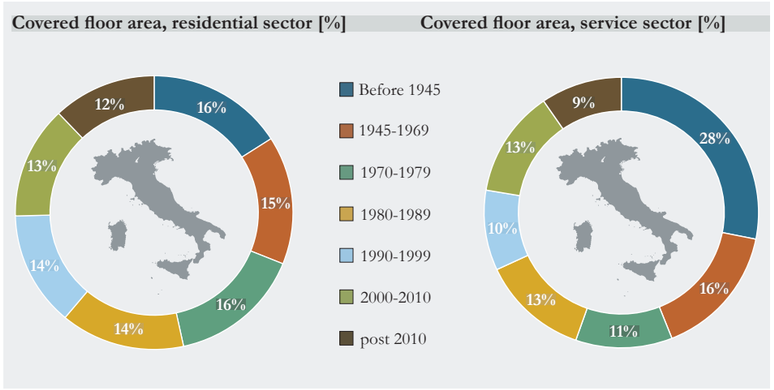



**Fig. 46**
*Split of the residential and service building stock raised per construction periods [%] in Italy. Source: Gevorgian et al. 2021, p.120.*

justified derogations will be implemented and monitored[39]. The Commission requires Member States to define criteria, report the estimated share of exempted buildings, and account for equivalent improvements or baseline treatment so that exemptions do not undermine national trajectories[40]. In this sense, the recast does not remove heritage exemptions, but it increases demands for transparency, proportionality, and demonstrable compatibility, placing greater responsibility on Member States to show that appropriate measures have been explored before derogations are used.

Against this evolving framework, recent Italian developments have sought to organise implementation in heritage contexts. In 2024 and 2025, the Ministry of Culture's Directorate-General of Archaeology, Fine Arts and Landscape (DG-ABAP) issued two circulars clarifying how energy efficiency should be handled for protected buildings and how procedures should operate. The 2024 circular establishes a ministry-led community of practice, appoints contact points within Regional Directorates and Superintendencies, and promotes coordination to align authorisation procedures, improve submission quality, and share evidence from completed projects[41]. The 2025 circular addresses recurring interpretative questions on the application of Legislative Decree 192/2005, reaffirming the exclusion regime for listed buildings while clarifying residual obligations, notably energy certification and the operation and inspection of building services, and reiterating that exclusion is admissible where compliance would entail a substantial alteration under cultural heritage and landscape law[42].

In parallel, European research programmes and guidance have progressively supported a shift from rigid compliance towards significance-led improvement.

39 European Commission 2025.

40 European Commission 2024, article 9.

41 MiC 2024.

42 MiC 2025.



Funded projects and expert networks[43] have promoted interdisciplinary exchange and tested solutions compatible with heritage requirements, while technical guidance has consolidated a shared process logic: knowledge building, significance assessment, diagnosis, and option appraisal before selecting measures[44]. This orientation is formalised at European level in EN 16883:2017, which frames energy upgrading in historic buildings as a structured decision process rather than the pursuit of fixed targets[45]. In Italy, the 2015 MiBACT "Guidelines for improving energy efficiency in cultural heritage" adopt a similar sequence, combining historical-architectural analysis with an audit tailored to traditional buildings and a repertory of compatible measures discussed in terms of risks, reversibility, and impacts on heritage values[46]. The aim is to optimise performance where feasible without displacing heritage values, using proportionate measures that are compatible, moisture safe, and as reversible as practicable. Priority is given to minimal, fabric-conscious actions, planned maintenance, and the recovery of correct environmental behaviour[47]. As a result of these initiatives, the notion of "energy improvement" has become established, and it is understood as distinct from full compliance with standards designed for new buildings: it suggests that every historic building should pursue a measured enhancement of its energy performance, calibrated to its specific characteristics and constraints, avoiding the indiscriminate application of uniform benchmarks[48]. This concept finds a parallel in the practice of seismic strengthening of historic heritage, where the objective is not always full compliance with current codes, but rather a proportionate improvement of structural safety[49].

International practice offers comparable signals. Although developed in different regulatory settings, guidance in England and Ireland is useful here because it consolidates a transferable process logic for traditionally constructed buildings. It rejects one-size-fits-all targets in favour of compatibility, moisture safety, and incremental pathways that aim for measurable improvement without compromising heritage significance[50].

Despite these advances, critical issues remain. Much research and many

43 Among the most influential are 3ENCULT (Efficient Energy for EU Cultural Heritage, 3ENCULT n.d.), EFFESUS (Energy Efficiency for EU Historic Districts' Sustainability, European Commission 2016), RIBuild (Robust Internal Thermal Insulation of Historic Buildings, European Commission 2021b), and IEA SHC Task 59 (IEA SHC - International Energy Agency Solar Heating and Cooling Programme n.d.).

44 Pracchi 2017.

45 CEN - European Committee for Standardization 2017.

46 MiBACT 2015. Although non-binding, the document is structured like a technical handbook and follows the classical Italian restoration sequence: knowledge first, diagnosis second, design last.

47 Battisti 2016.

48 Pracchi 2017.

49 Pracchi, Rosina 2013, p. 212.

50 Government of Ireland 2023b; Historic England 2025a.

interventions still operate at the scale of individual buildings, while EU timelines and governance now require approaches that can be applied across diverse building stocks[51]. This creates particular challenges for historic portfolios, which are heterogeneous, subject to multiple layers of protection, and costly to retrofit[52]. In practice, exemptions can also function as an administrative or economic shortcut, leaving parts of historic stock outside renovation trajectories and increasing the risk of neglect, abandonment, and loss of use[53]. More broadly, many regulatory instruments remain calibrated to contemporary construction and quantitative benchmarks such as U-values, minimum system efficiencies, and uniform performance classes. Historic buildings, by contrast, often rely on thick masonry, original timber windows, natural ventilation, and elevations of explicit architectural value, making it difficult to meet new-building standards without invasive works[54] (Fig. 47).
Further research and policy development are therefore required to move from exemplary building-scale projects to stock-level replication, including harmonising documentation and metrics, strengthening post-intervention monitoring, and improving the coupling between heritage-value assessment and robust building evaluation so that decisions can be justified on both conservation and performance grounds[55].

51 Lidelöw *et al.* 2019, p. 233.
52 Herrera-Avellanosa *et al.* 2024.
53 Lucchi, Pianezze 2013, p. 31.
54 Mazzarella 2015.
55 Herrera-Avellanosa *et al.* 2024.

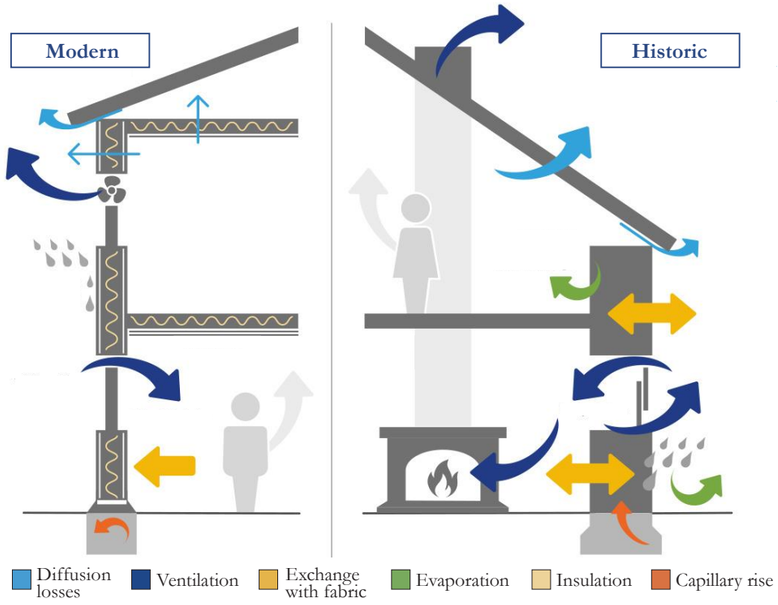



**Fig. 47**
*Schematic drawing representing the difference between traditional buildings and modern buildings. Source: Historic England 2020, p. 16.*





### 3.2.2 Renewable Energy Sources and Renewable Energy Communities

The most recent European framework, including Directive (EU) 2024/1275, links decarbonisation targets to a broader deployment of renewable energy, including on-site generation and digital control[56]. It also retains the possibility of exempting officially protected buildings where compliance would entail unacceptable visual or material alteration[57]. In heritage settings, this strengthens the rationale for solutions that are low-impact, compatible with significance, and, where feasible, reversible.
Early operational guidance on the integration of micro renewables in heritage buildings was also developed outside the Mediterranean context, for instance in the UK with Changeworks' "Renewable Heritage" (2009)[58]. While produced for a different regulatory and climatic setting, it remains relevant here as an early precedent for an approach based on visual discretion, careful detailing, reversibility, and heritage impact assessment, which is consistent with the logic reiterated by more recent European and Italian frameworks.
Technological development has increasingly focused on discreet or building-integrated photovoltaics, which tend to be more acceptable than highly visible installations in sensitive landscapes such as historic centres[59]. Recent work on PV in heritage contexts shows that thin, coloured, or reduced-profile modules can be aligned with traditional roof geometries and installed on roof pitches with limited impact on the roofscape (Figs. 48-49), or integrated as architectural components[60] (Fig. 50). Building-integrated solutions designed to mimic traditional materials, such as photovoltaic roof tiles, provide a further option where conventional panels would be visually intrusive. Such systems have been tested in high-significance contexts, including archaeological sites such as Pompeii[61] (Figs. 51). The examples in Figs. 48 to 52 are presented as illustrative applications and product typologies.
Where roofs are highly exposed or interventions would remain visually disruptive, district or off-site renewables may be preferable. Locating generation in nearby buildings or less sensitive areas (Fig. 52) can reduce direct physical intervention on protected envelopes[62]. In compact historic fabrics, district heating and cooling[63] can also be effective because shared

56 European Commission 2024, point 35.
57 European Commission 2024, article 9, paragraph 6, letter a.
58 Changeworks 2009.
59 Lucchi *et al.* 2023.
60 Renè Di Rocco *et al.* 2024.
61 Bruni, Papi 2019.
62 Lucchi *et al.* 2020.
63 e.g. Ju *et al.* 2023. District heating and cooling generate heat or chilled water centrally and distribute it via insulated pipes to multiple buildings. They can enable efficient low-carbon sources, reduce rooftop or façade equipment, and in dense historic areas help cut emissions and limit plant within protected envelopes.



**Fig. 48 (above)**
*Architectural integration of terracotta-coloured "Silk Nova Orange" photovoltaic modules on the main roof of a repurposed 1930s monastery. Source: futurasun.com*

**Fig. 49 (centre, left)**
*Building-integrated PV panels designed to match traditional roofs and façades in sensitive settings. Source: futurasun.com*

**Fig. 50 (centre, right)**
*Invisible photovoltaic roof tiles. Source: greenme.it*



**Fig. 51 (below, right)**
*House of the Vettii, Pompeii (NA), Campania, where invisible photovoltaic roof tiles were installed. Source: edition.cnn.com*

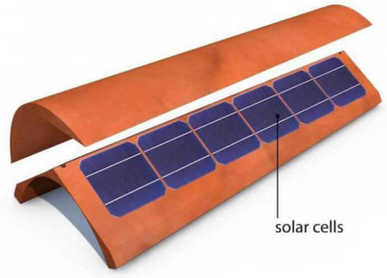



**Fig. 52 (below, left)**
*Farmhouse Huber, Rodeneck (BZ), Trentino Alto-Adige: nearby-area PV enabling decentralised energy production. Source: Renè Di Rocco et al. 2024, p. 12.*









networks reduce the need for multiple intrusive retrofits and concentrate maintenance and plant rooms in discreet energy centres[64].

Renewable Energy Communities (RECs) similarly operate at neighbourhood scale, organising the production, sharing, and storage of renewable energy across multiple buildings (Fig. 53). As locally based, citizen-governed entities, RECs can aggregate demand, support shared storage, and contract district services or proximate generation, distributing benefits across several historic properties while minimising interventions on each[65]. Their legal basis lies in the Clean Energy for All Europeans Package, in particular the Renewable Energy Directive (EU) 2018/2001 and the Electricity Market Directive (EU) 2019/944, which require Member States to establish enabling frameworks, ensure open and voluntary participation, and allow energy sharing through the public grid[66].

Recent analytical work points to socio-technical benefits, notably a shift from maximising performance in each individual building to optimising performance across the ensemble[67]. Empirical evidence also indicates that predictable enabling frameworks and remuneration are decisive. In Italy, implementing acts[68] under Legislative Decree 199/2021[69] introduced premium tariffs for shared energy and investment support, after which collective self-consumption schemes and RECs increased, with 2024 data reporting more than 150 active shared-energy configurations[70]. Comparative EU studies similarly find that, when integrated into distribution-system planning, RECs can help address energy poverty and provide flexibility services, although replication remains constrained by transaction costs, limited technical capacity, and fragmented local governance[71].

At municipal scale, the Covenant of Mayors for Climate and Energy provides an EU-backed framework through which cities commit to local Sustainable Energy and Climate Action Plans (SECAPs), supported by Joint Research Centre guidance on baselines, adaptation, monitoring, and reporting[72]. In practice, it helps translate EU targets into settlement-scale action and can connect neighbourhood initiatives such as RECs with wider decarbonisation pathways, including those outlined in the Fit for 55 package[73].

64 Volkova *et al.* 2023.

65 Barabino *et al.* 2023.

66 European Commission 2018, article 22; European Commission 2019b, articles 2, 16.

67 European Commission 2020b; Rossetto 2023.

68 MASE - Ministry of Environment and Energy Security 2024.

69 Italian Government 2021f

70 Energy & Strategy Group 2024.

71 Magni *et al.* 2024.

72 European Commission n.d.e; Global Covenant of Mayors for Climate & Energy n.d.; Davide *et al.* 2025.

73 European Council 2025. Fit for 55 package is the 2021 legislative programme to cut EU net greenhouse-gas emissions by at least 55% by 2030 and to set the path to climate neutrality by 2050.

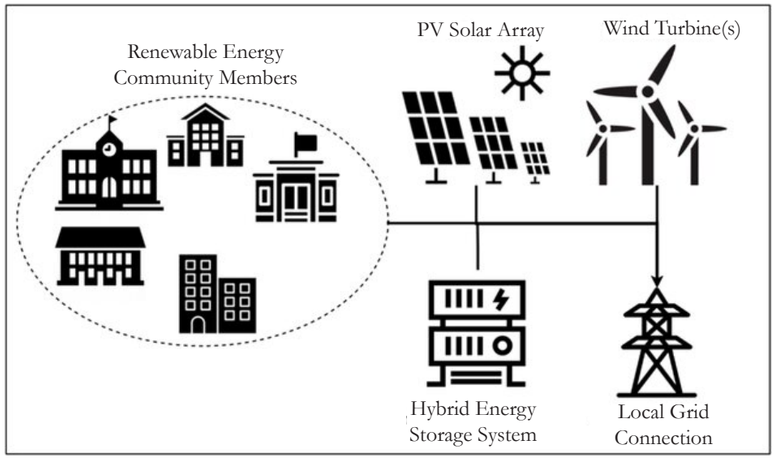



**Fig. 53**
*Renewable energy community system architecture. Source: Dehouche, Garner 2023, p. 5.*

### 3.2.3 Regional Implementation: Sardinia and Territorial Energy Instruments

Sardinia is a useful case to discuss regional implementation in a Mediterranean context because it combines three conditions that tend to collide in practice: an insular energy system, a heritage-rich and landscape-sensitive territory, and an accelerated push for renewable deployment. This combination has pushed the Region to translate national and EU requirements into operational tools while simultaneously strengthening territorial safeguards.

On building energy performance, regional directives adopted with DGR 70/11 and subsequent updates align calculation methods and minimum requirements with national rules, while organising certification procedures at regional level[74]. In parallel, the Regional Environmental and Energy Plan (PAEER) 2013-2020 framed the building stock as a priority field for reducing demand and increasing the share of renewables, through actions such as building an information base, supporting coordinated retrofits, and enabling incentives for local authorities and private actors[75]. This data-driven approach has recently been strengthened through CERESar, the Regional Energy Cadastre of Buildings, integrated within the regional environmental information system (SIRA). From January 2025, CERESar has been introduced as the official platform for the management and registration of Energy Performance Certificates (APE) in Sardinia, aiming to standardise procedures and provide a reliable statistical base for monitoring and future

74 Autonomous Region of Sardinia 2016a; Autonomous Region of Sardinia 2016b.

75 Autonomous Region of Sardinia 2019. With this directive the Region has explicitly aligned with the national framework derived from EU Directive 2002/91/EC and national Legislative Decree 192/2005.





measures[76]. This data-driven approach to mapping and understanding the building stock is consistent with the national shift, following the EPBD recast, towards renovation strategies grounded in structured datasets and long-term planning[77].

Sector-specific instruments are also emerging. In 2024, ARES Sardegna issued technical guidance for improving energy efficiency in healthcare buildings, starting from energy audits and treating envelope and systems as an integrated whole, with repeatable measures across facilities[78]. Although not written for listed heritage, it is significant as a regional translation of national principles into an operational workflow that can inform other public building categories.

Financially, the Region has activated grant-based measures that support voluntary upgrades rather than relying on obligations alone. For instance, in late 2025 Sardinia launched a programme supporting energy efficiency and self-consumption for small and medium enterprises, including renewables and storage[79]. Within the PR FESR Sardegna 2021-2027, "Transizione verde" actions also fund energy upgrades in public buildings and plants, including municipal assets and public lighting[80].

From the viewpoint of historic buildings, however, the picture is still uneven. Landscape and heritage safeguards are strong and clearly articulated through the Regional Landscape Plan and related guidance, which condition retrofit options through criteria of material compatibility and visual integrity[81]. However, none of the main Sardinian documents on energy contains a technical section specifically calibrated on protected or not protected historic buildings.

For renewable energy sources the commitment of the Region has been significant, probably fuelled by the highly mediatised debate over the rapid expansion of onshore and offshore wind in Sardinia, where concerns about cumulative landscape impacts, procedural uncertainty, and community consent have been prominent[82]. Sardinia had already adopted guidance on PV landscape integration in 2008, introducing visual-mitigation and compatibility criteria and safeguards in proximity to historic and protected areas[83]. Within these areas, ground-mounted photovoltaic fields are discouraged or excluded, and any proposal must prove compatibility with the protected fabric and key views identified by the RLP, paying close attention to scale, materials, reflectance, and visibility from public spaces. Interventions should prioritise

76 Autonomous Region of Sardinia 2024b.

77 Italian Government 2020d, article 5.

78 ARES Sardegna - Regional Health Company 2024.

79 Autonomous Region of Sardinia 2025c.

80 Autonomous Region of Sardinia 2024c.

81 Autonomous Region of Sardinia 2006d, articles 52 and 49-51 on

82 Greenpeace 2024.

83 Autonomous Region of Sardinia 2008d.

discreet, building-integrated solutions on existing roofs that are not visible from principal elevations, supported by a landscape-impact assessment with mitigation measures and carried out in agreement with the heritage authorities[84]. More recently, Regional Law 20/2024 introduced a framework that classifies suitable, ordinary and non-suitable areas for renewable plants, explicitly requiring minimisation of landscape impacts and compliance with the Regional Landscape Plan, while steering PV towards built surfaces and industrial or service areas[85]. The Region then approved detailed procedures for the "intesa" request by municipalities (DGR 15/32 of 19 March 2025), operationalising participation and assessment steps for proposals that would otherwise fall in non-suitable areas[86]. In August 2025, the Regional Government also adopted a proposal for terrestrial acceleration zones, mainly mapped over industrial estates and already-artificial surfaces, with exclusions linked to protected landscapes[87].

Importantly, this regulatory landscape has not remained stable. A national constitutional challenge was filed in early 2025, and the Constitutional Court's decision no. 184/2025 clarified that designating an area as "non-suitable" cannot amount to an automatic, blanket ban, requiring regional rules to align with the national authorisation regimes and their proportionality logic[88]. This jurisprudence is relevant for heritage contexts because it reinforces the need for documented, case-by-case determinations, rather than categorical exclusions, while still allowing strong protection where justified by significance and landscape values.

Community energy initiatives are also emerging on the island, with early experiences reported around Macomer and the establishment of an industrial community in the Macchiareddu area in July 2024. While still evolving, such initiatives point to a pathway that can reduce pressure on individual historic buildings by shifting part of the decarbonisation effort to neighbourhood-scale sharing and proximate generation, provided that governance capacity and permitting clarity keep pace[89].

Overall, the Sardinian case highlights both territory-specific constraints and actionable opportunities. The institutionalisation of an energy cadastre (CERESar) can provide the evidence base for targeted policies that explicitly include historic fabric, and the ongoing recalibration of renewable siting rules suggests a move from broad prohibitions towards more robust, transparent, and documented assessment frameworks.

84 *Ivi*, pp. 4, 6, 11, 14.

85 Regional Council of Sardinia 2024.

86 Autonomous Region of Sardinia 2025d.

87 Autonomous Region of Sardinia 2025e.

88 Autonomous Region of Sardinia 2025f.

89 Associazione Elettrica Sarda 2025; Autonomous Region of Sardinia 2025g. By 2025 press surveys count roughly 15 recognised communities across the island, with further groups in formation.





## 3.3. Conflicts and Challenges Between the Green Transition and Historic Landscape Protection

Over the past two decades, "sustainability" has become a widely used term in architecture and urban planning. While this expansion has helped mainstream environmental concerns, it has also encouraged uses that are vague, unverified, or primarily reputational. In such cases, sustainability shifts from a framework for balancing environmental, social, economic, and cultural dimensions to a label that can legitimise business-as-usual through the language of ecological responsibility[90]. This dynamic is often discussed under the umbrella of "greenwashing", understood as the exaggeration, selective presentation, or misrepresentation of environmental claims to strengthen a project's image, secure funding, or appeal to eco-conscious stakeholders[91].

These tensions are particularly acute in historic contexts, where energy upgrades can conflict with material authenticity, visual integrity, and cultural continuity. In response, recent criteria and methodological approaches increasingly emphasise demonstrable performance and transparent trade-offs, moving beyond single-issue claims. Metrics and assessment tools such as whole-life carbon, life-cycle resource use, and system-wide effects help differentiate genuine environmental benefits from merely performative measures, and support decisions that acknowledge both environmental targets and heritage significance.

### 3.3.1 Sustainability Discourse and Greenwashing in the Built Environment

Within the construction industry, greenwashing tends to recur through a limited set of tactics, including exaggerated environmental claims, selective reporting, and vague terminology. The indiscriminate use of words such as "natural", "green", or "sustainable" can increase ambiguity and make claims difficult to verify[92]. Such practices are widely recognised as ethically problematic and environmentally counterproductive because they divert attention from measurable impacts, erode public trust, and slow the uptake of genuinely low-impact strategies[93].

In architectural practice, accusations of greenwashing often concern the use of superficial eco-aesthetics, for instance green roofs or vegetated façades applied to projects whose overall performance is not demonstrated[94].

90 European Commission n.d.f; Schuetze, Chelleri 2016.

91 Delmas, Cuerel Burbano 2011.

92 CMA - Competition & Markets Authority 2021.

93 United Nations n.d.b.

94 Sigrist 2023; Mitrovic 2025.

Although such systems can provide heat-island mitigation and storm-water benefits, their sustainability depends on whole-life inputs and context. Substrates, irrigation, fertilisation, and maintenance burdens should be accounted for, and performance can vary substantially across climates. For this reason, building-level evaluations should follow recognised whole-life carbon approaches, which quantify emissions across the full life cycle of a built asset and increasingly incorporate specific guidance for refurbishment and existing buildings[95]. A central weakness of greenwashed claims is precisely the absence of a life-cycle perspective, since environmental responsibility should address material extraction and production, construction, operation, maintenance, and end-of-life stages[96]. Fig. 54 is included to make this methodological point explicit by summarising the Life Cycle Assessment logic that underpins whole-life carbon accounting.

A similar caution applies to on-site renewables such as photovoltaics. PV can materially reduce operational emissions when coherently integrated into an energy strategy, yet modules degrade over time and have finite service lives. This introduces replacement needs, costs, and waste streams that should be captured within whole-life carbon analysis. Reported degradation rates are commonly around 0.5 per cent per year[97], and typical lifetimes are often in the 25 to 30-year range[98]. Without robust end-of-life routes, large waste volumes are projected[99]. In the European Union, PV panels fall within the Waste Electrical and Electronic Equipment regime, which sets recovery and recycling targets for this category[100]. Fig. 55 is included to clarify why end-of-life management matters alongside operational savings, by showing the scale of projected PV waste as early generations of modules reach end of life[101].

At the urban scale, the branding of neighbourhoods and municipalities as eco-cities or green communities, whether existing or newly built, can similarly rest on selective and highly visible interventions that prioritise attractiveness and growth narratives over systemic transformation. This pattern is extensively discussed in the literature on eco-urbanism and smart-sustainable city branding[102].

Overall, the misuse of "sustainability" and the widespread presence of greenwashing in the built environment point to the need for conceptual clarity and methodological rigour, with claims anchored to transparent metrics, stated boundaries, and verifiable performance.

95 e.g. RICS - Royal Institution of Chartered Surveyors 2024.

96 CEN – European Committee for Standardization 2011.

97 Jordan, Kurtz 2012, p. 1.

98 Wiser et al. 2020, p. 1; U.S. Department of Energy 2025.

99 IEA 2018; Gönen, Kaplanoğlu 2019.

100 European Commission 2012b, Attachment V, Part 3. The WEEE regime has set minimum targets of 85 percent recovery and 80 percent recycling by mass for this category.

101 IEA, IRENA - International Renewable Energy Agency 2016, p. 86.

102 e.g. De Jong *et al.* 2019; Neidig *et al.* 2022.





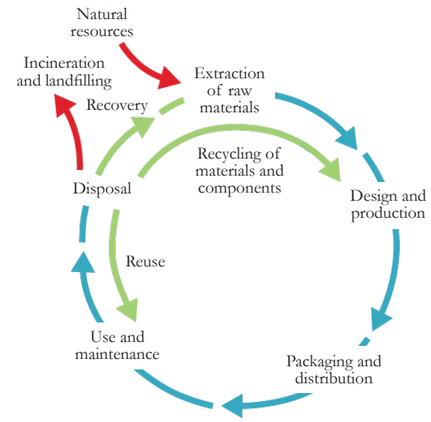



**Fig. 54 (above)**
*Life Cycle Assessment (LCA) stages used to structure whole-life carbon accounting in buildings (illustrative framework for the life-cycle perspective discussed in Section 3.3.1). Source: IEA 2024, p. 2.*

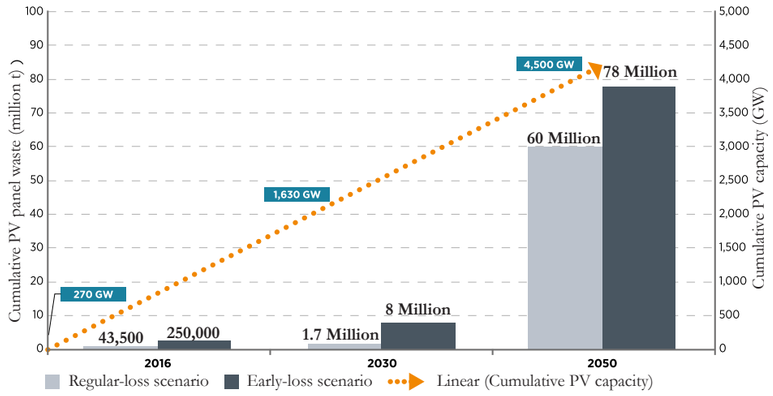



**Fig. 55 (below)**
*Overview of global PV panel waste projections, 2016–2050 (included to illustrate the scale of expected waste streams in the absence of robust end-of-life routes). Source: IEA, IRENA 2016, p. 12.p. 12.*

### 3.3.2 Limits of Current Operational Approaches to Retrofit in Mediterranean and Sustainable Heritage Contexts

A recurring limitation in retrofit practice is the transfer of measures developed for heating-dominated contexts into Mediterranean and historic settings without sufficient climatic and material contextualisation[103]. This can lead to sub-optimal results and, in some cases, unintended risks for comfort and fabric. Building-envelope insulation is a representative example. Across Europe, insulation is associated with significant savings in colder climates where heating demand dominates, whereas in Mediterranean regions, where cooling loads and solar gains are critical, the marginal benefit of very high insulation levels can be more limited. Comparative cost-optimal analyses by the European Commission's Joint Research Centre, including tests in

103 Shrubsole *et al.* 2014; Filippidou, Jiménez Navarro 2019; Gori *et al.* 2021; Calama-González *et al.* 2022.



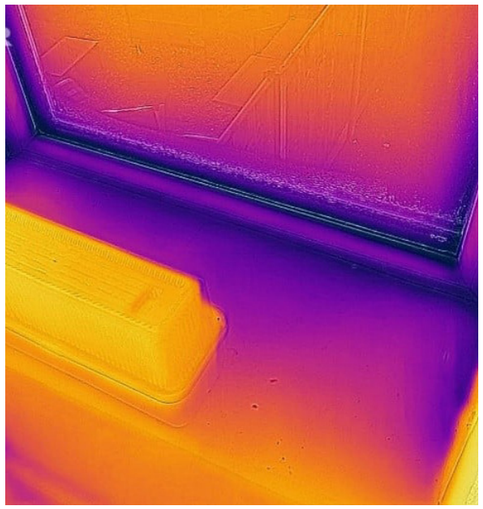


**Fig. 56**
*A case study of condensation in a mid-Victorian building in UK. The property was renovated including insulated plasterboards in the main walls and modern PVC windows. The thermal image shows cooler 'blue' areas around the window where condensation is forming. Source: sava.co.uk*

Germany and Greece, indicate that southern contexts often favour balanced packages, combining moderate insulation with efficient heating and cooling systems, solar control, and ventilation strategies, rather than pursuing maximum insulation alone[104].

Monitoring studies in southern Spain reinforce this point: insulation by itself does not consistently prevent summer overheating unless combined with complementary measures such as effective solar shading and night-time ventilation[105]. In historic buildings, these operational limits intersect with conservation constraints. Guidance on "sustainable heritage" stresses that performance improvement should be pursued within boundaries defined by heritage significance and technical compatibility, with explicit attention to minimal intervention and, where feasible, reversibility[106]. Traditional solid-wall construction relies on vapour-open behaviour and moisture buffering. Introducing vapour-tight layers, including internal insulation systems, can reduce drying capacity and increase the risk of interstitial condensation, with potential damage to finishes and fabric if detailing, hygrothermal assessment, and moisture management are inadequate[107]. In addition, replacement-led retrofits can increase whole-life greenhouse-gas emissions once production, transport, maintenance, and end-of-life impacts are included, which is why sector guidance increasingly prioritises retention and repair as low-carbon first principles[108].

104 Filippidou, Jiménez Navarro 2019.

105 Calama-González *et al.* 2022.

106 IEA SHC 2021, pp. 25-29.

107 English Heritage 2012, pp. 2-4.

108 National Trust for Historic Preservation 2011; RICS - Royal Institution of Chartered Surveyors 2024, p. 29.







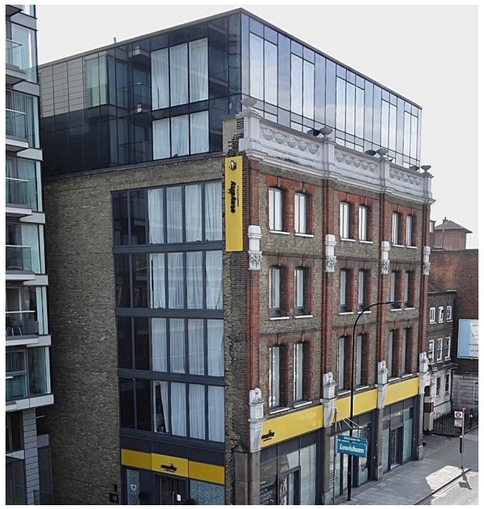


**Fig. 57**
*Extreme example of "facadism": original façade retained, internal fabric entirely replaced or to be replaced. Source: core77.com*

Window interventions illustrate the same trade-offs. Replacing traditional joinery with highly airtight frames can suppress background ventilation and alter indoor moisture balance, increasing humidity and mould risk unless deliberate ventilation is provided (Fig. 56). In Italy, fiscal incentives have sometimes encouraged extensive window and envelope substitution to meet quantitative performance thresholds[109]. Where such interventions are poorly targeted or not accompanied by ventilation and solar-control measures, they can produce limited comfort benefits while causing irreversible losses of historic material and craftsmanship[110]. This reinforces the need for retrofit strategies that are evidence-led and explicitly designed for Mediterranean summer performance as well as winter efficiency.

A further critical issue concerns interventions that preserve outward appearance for aesthetic or regulatory reasons while substantially altering internal material and spatial qualities. The phenomenon of façadism[111] shows how façade-retention strategies can compromise integrity and authenticity, turning conservation into a visual simulacrum rather than safeguarding substance[112] (Fig. 57). For historic settlements, this is not only a cultural loss but also a missed opportunity, since many passive climatic features reside precisely in the construction logic and spatial organisation of traditional fabric.

109 Among many laws and decrees, Italian Government 2006a; Italian Government 2013a (Ecobonus); Italian Government 2020c (Superbonus).

110 Pracchi, Rosina 2013, pp. 212-214.

111 Façadism is usually described as the practice of preserving historical façades and the construction of new buildings behind them.

112 e.g. Kyriazi 2019; Plevoets 2021.

### 3.3.3 Methodological Approaches and Perspectives for Sustainable Built Environments

Sustainability assessment in heritage contexts can drift towards single-parameter optimisation, for instance energy use alone, even when decisions involve interdependent cultural, environmental, social and economic effects[113]. Recent reviews therefore argue for multi-criteria approaches that make trade-offs explicit and allow values and performance to be considered together. Evidence from historic-building retrofit research similarly suggests that designing to meet headline numerical targets can overlook context-specific drivers of performance, including climate, occupant behaviour, and moisture risk, with implications for comfort, durability and conservation outcomes[114].
A growing body of literature accordingly advocates integrated methods that consider whole-life and cross-domain impacts rather than isolated operational metrics[115]. Methodologically, Multi-Criteria Decision Analysis (MCDA) and Life Cycle Assessment (LCA) are often combined to balance operational performance with embodied impacts and heritage-related constraints. At the urban and district scale, this shift is increasingly reflected in leading certification systems, which are not presented here as prescriptive models for historic centres, but as indicators of a wider move towards structured, outcome-oriented assessment. LEED for Cities and Communities v4.1 organises evaluation around Key Performance Indicators across domains such as energy, water, waste, mobility and quality of life, with a more limited emphasis on embodied and whole-life carbon at district level[116]. By contrast, DGNB for Districts specifies district-scale criteria that explicitly include life-cycle assessment for projects and infrastructures, as well as urban climate performance, land-use efficiency and ecological quality[117].
In practice, MCDA translates objectives into criteria, incorporates stakeholder priorities through transparent weighting, and scores alternatives to reveal trade-offs and identify robust options. Sensitivity analysis can then test how results change under different assumptions[118]. Coupled with LCA, which quantifies embodied and operational impacts across all life stages, MCDA and MCDM enable transparent comparisons between alternatives. Figure 58 is included because it clarifies how life-cycle thinking and the comparison of alternatives can be organised into a transparent decision logic, which is particularly relevant when environmental targets must be balanced with

113 e.g. Mecca 2023.

114 e.g. Salvia *et al.* 2020; Historic England 2025b.

115 e.g. Salvia *et al.* 2020

116 U.S. GBC - U.S. Green Building Council 2024. LEED for Cities & Communities v4.1 was launched in 2019 and updated through 2023–2024.

117 DGNB - Deutsche Gesellschaft für Nachhaltiges Bauen n.d.

118 For more information on the functioning of MCDA see for example Więckowski, Salabun 2023.





heritage constraints.
When paired with Heritage Impact Assessment (HIA), these tools can further support choices that improve environmental performance without undermining authenticity or cultural significance. HIA establishes the heritage baseline and significance, anticipates impacts on fabric, setting and use, compares reasonable alternatives, and defines avoidance, mitigation and monitoring measures[119]. Integrating HIA with MCDA and LCA produces a traceable, evidence-led decision pathway in which cultural values are assessed alongside energy, carbon and cost outcomes, supporting solutions that are both conservation-informed and climate-responsive.
Chapter 3 has shown that current implementation often oscillates between two unsatisfactory extremes: exemptions that postpone improvement and accelerate neglect, or compliance-driven interventions that privilege measurable thresholds. At the same time, the rapid scaling of renewables and the politicisation of siting decisions, particularly visible in Sardinia, reveal how easily the green transition can become a source of territorial conflict when governance, evidence and consent do not keep pace. These dynamics expose the limits of both one-size-fits-all technical prescriptions and purely discursive invocations of sustainability, and they highlight a practical gap: what is missing is not more principles, but a repeatable way of translating significance-led conservation and climate response into comparable options, explicit trade-offs and justifiable decisions.

119 ICOMOS 2011

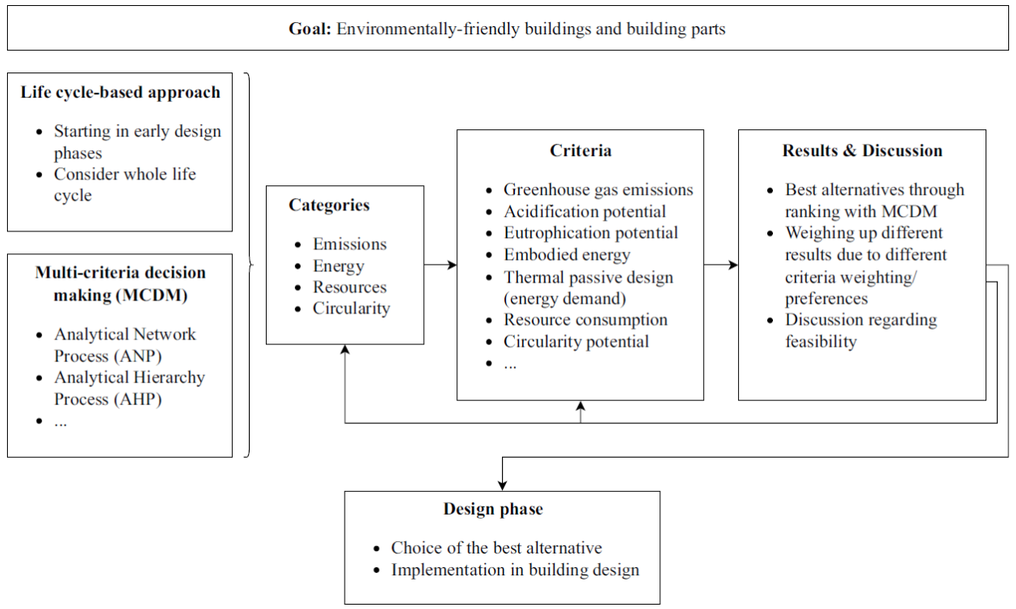



**Fig. 58**
*Systematic approach for life cycle-based MCDM, in theis case in the planning and design process. The same framework can be used in the case of interventions in existing buildings with the goal of environmentally friendly solutions.*
*Source: Theilig et al. 2025, p. 1979*

# Part 2.

## Protocol of Analysis and Stategy Development for Climate-Sensitive Urban Interventions in Historic Villages: Methodological Framework and Case Study Application

# Chapter 4.
# A Methodological Framework: Strategies and Tools for Designing Environmental Quality

"*The valorization of local microclimatic factors, with the aim of a general improvement of living conditions in urban areas, makes it possible to redefine the characteristics of the anthropized environment in relation to the physical and immaterial resources of places — such as climate, energy, air, water, soil, and vegetation — overcoming the limitations of the modes of urban development that have characterized the expansion of our cities*"[1].

Building on the policy and regulatory constraints discussed in Chapter 1, the climate-tuned logic of historic fabrics outlined in Chapter 2, and the unresolved tensions between climate targets and heritage practice synthesised in Chapter 3, this chapter translates those premises into an operational protocol. In particular, it responds to the gap identified in the previous chapters: not a lack of principles, but the need for a repeatable workflow that can turn significance-led conservation and climate response into comparable options and justifiable decisions at settlement scale.

The chapter proposes an interdisciplinary methodological framework in which outdoor microclimate and thermal comfort act as a diagnostic and decision-support lens.

By combining knowledge building, spatial diagnostics, and simulation-based testing, the framework aims to formalise a structured, settlement-scale protocol that integrates conservation principles with microclimatic assessment, to identify the main morphological, material, and vegetation-related drivers of local microclimate, and to support the testing and comparison of heritage-compatible mitigation scenarios through transparent outputs that can inform municipal planning and project briefs.

Accordingly, the chapter introduces the key concepts and measurable constructs that underpin the workflow, reviews relevant research and planning tools, adapts the Urban Microclimate Design approach to the constraints of historic villages, and organises the analytical and design phases that will be applied to Osidda in Chapter 5.

1 D'Olimpio 2008, p. 6.





## 4.1 Toolkit and Pillars for the Development of the Methodology

This section presents the toolkit, core concepts, and definitions that underpin the proposed methodology. Before setting out methods, it is essential to understand the physical phenomena at stake and the terms used to describe them. Therefore, in line with the climate–morphology relationships outlined in Chapter 2, the following concepts are outlined: the urban microclimate, showing how form, materials, vegetation, and site conditions mediate local energy exchanges and pedestrian-level experience; the climate–environmental components most relevant to urban microclimate, with emphasis on radiation, ventilation, and humidity, together with the surface energy balance that links them; define the urban heat-island phenomenon; and review thermo-hygrometric comfort, including the main outdoor indices. Taken together, these pillars provide a common language and a set of measurable constructs that make the subsequent methodology intelligible and transferable.

### 4.1.1 The Urban Microclimate

In order to establish an effective design process, particularly in pre-existing urban environments, it is necessary to analyse the physical components of the context in which one operates, ranging from settlement patterns at the urban scale to the individual building unit. These components are determined by various requirements, among which the climatic factor is fundamental. Climate is the product of the interrelation between the biophysical and microclimatic aspects of the context: the former include the characteristics of a given geographical setting (topological, lithological, hydrogeological, vegetational, etc.), while the latter comprise the climatic factors of a place (air temperature, precipitation, wind speed and direction, air humidity, etc.)[2]. Climate differs from weather in that it represents a statistical generalisation defining the recurrent atmospheric-meteorological conditions of a given region, whereas weather refers to the prevailing conditions at a specific moment in time[3].

Within a macro-area, the climatic conditions of a specific location are influenced by a multitude of local factors, giving rise to a microclimate. Among these, the topographical configuration of the area plays a primary role, as it determines exposure to solar radiation and influences the movement of air masses, while the geographical setting may affect the moisture content of the air depending, for example, on the proximity of watercourses[4]. The nature of the soil significantly affects the microclimate and air temperature, depending

2 D'Olimpio 2008, p. 5.

3 Szokolay 2004, p. 22; D'Olimpio 2008, p. 11;

4 Olgyay 1981, pp. 83-91.

on whether the material is natural or artificial, and on its coefficients of absorption and reflection of solar radiation, as well as its thermal properties and permeability. Vegetation, through processes of evapotranspiration, can also increase air humidity while lowering air temperature[5]. Some studies demonstrate that, in summer, the temperature above a grass-covered surface may be approximately 5 to 7 degrees lower than that of bare soil, while the temperature beneath a tree at midday is about 3 degrees lower than that of the surrounding environment[6]. Furthermore, the presence of three-dimensional objects (buildings, walls, trees, shrubs, etc.) influences wind flow, contributes to shading, and subdivides space into more limited areas, thereby fostering the creation of specific microclimatic conditions[7].
Urban settlements are characterised by a specific 'urban microclimate', resulting from the interaction between the built environment and climatic and environmental factors. The main elements influencing this type of microclimate include the reflective properties of solar radiation (also referred to as 'albedo') and the thermal characteristics of surfaces, both at ground level and on walls and buildings; soil permeability and the consequent capacity for evapotranspiration, generally reduced when artificial and impermeable materials are employed; the presence of vegetation or vegetated surfaces; the rate of evaporation and runoff of stormwater; the presence of obstacles to wind flow and its velocity; the production of heat, for instance due to mechanical air conditioning in buildings, heating systems, or engine operation; and, finally, the emission of atmospheric pollutants, likewise associated with, for example, climate-control systems, heating, or transportation[8].
In summary, the climatic-environmental components, such as solar exposure, ventilation, and air humidity, modify their intensity and modes of interaction according to the specific context, whether urban or rural, and the elements contained within it[9].

### 4.1.2 The Climate-Environmental Components

*Insolation*
Incident solar radiation on a surface can be divided into three main components: direct, diffuse, and reflected. Direct solar radiation is that which reaches the surface after passing through the atmosphere, which contains dust and particles of various kinds capable of scattering part of the energy, thereby reducing its heating power. For this reason, winter solar rays, which pass through the atmosphere at a greater inclination and thus encounter

5 D'Olimpio 2008, pp. 18-19.
6 Olgyay 1981, p. 92.
7 Szokolay 2004, p. 73.
8 D'Olimpio 2008, p. 23.
9 *Ibidem.*





more particles, have less heating power than summer rays, which traverse the atmosphere more perpendicularly. Moreover, the amount of heat received by a surface increases as the solar rays strike it more perpendicularly. Diffuse solar radiation is that portion of solar radiation which, after interacting with dust and particles in the atmosphere, still reaches the ground but in an indirect and scattered manner. Under overcast or hazy conditions, the diffuse component increases while the direct component decreases. Reflected solar radiation, finally, is the portion of solar radiation that is re-emitted into the environment depending on the albedo characteristics of the surfaces upon which it strikes, resulting in a loss within the overall energy balance of the surface[10].
In addition to these three components, characterised by short-wave radiation, it is also necessary to consider long-wave radiation, namely the energy re-emitted by surfaces in the form of thermal radiation, as well as atmospheric re-radiation, which partially compensates for the energy re-emitted by the surfaces[11]. Hence:

$$R = S_{dir} + S_{diff} + E_a - S_{ref} - E_s$$

Where
R: Radiative Balance [W/m$^2$]
$S_{dir}$: Direct solar radiation
$S_{diff}$: Diffuse solar radiation
$E_a$: Atmospheric back radiation
$S_{ref}$: Reflected solar radiation
$E_s$: Terrestrial longwave radiation
In the urban context, the overlying atmosphere is characterised by a higher concentration of particles, due to gaseous emissions, pollutants, and aerosols[12]. Therefore, the radiative balance in urban areas will be characterised, in addition to the previously defined terms, by a reduction in the amount of incident radiation.

$$R = (S_{dir} - r_a) + S_{diff} + E_a - S_{ref} - E_s$$

Where
$r_a$: direct radiation to be subtracted from the incident radiation

*Ventilation*
Ventilation, and in particular wind direction and velocity, in microclimatic contexts is influenced by the orographic and morphological characteristics of the site. Wind speed depends significantly on the 'surface roughness coefficient', which expresses the resistance exerted by the Earth's surface on the airflow. The roughness coefficient is minimal in the presence of obstacle-

10 D'Olimpio 2008, pp. 23-27.
11 *Ivi*, p. 30.
12 *Ibidem.*

free and uniform surfaces, such as plains or water bodies, and maximal in urban settlements, especially in the most densely built-up areas. Consequently, wind speed tends to decrease when air masses come into contact with urbanised zones. In urban areas, the layer of air that still maintains a 'free' stream is located at an altitude of about 500 meters above ground level, while at lower heights wind speed gradually decreases. The layer of air directly influenced by the Earth's surface is called the 'boundary layer'[13]. The wind speed at a given height above the ground can be calculated using the following formula[14]:

$$V(z) = (u^* / k) * \ln( (z - d) / z0$$

Where
V(z) = wind speed at height z [m/s]
z = height above ground level [m]
z0 = roughness length [m]
d = displacement height [m]
u* = friction velocity [m/s]
k = von Kármán constant (about 0.4)
ln( ) = natural logarithm

*Humidity*
The air humidity factor is closely linked to the structural and physical characteristics of the soil, whose conformation and composition may favor either the rapid runoff or the evaporation of surface water (such as rainwater), or its stagnation. This directly influences the amount of water that, through evaporation, contributes to increasing the level of humidity in the environment. Vegetation can also affect this parameter, through evapotranspiration processes that raise atmospheric humidity levels. However, these are not the only factors at play. In fact, the interaction between soil type, degree of solar exposure, and ventilation can represent an additional determining element. For example, high solar exposure combined with strong ventilation may promote rapid evaporation of moisture, reducing the stagnation of humid air. In urban areas, the percentage of relative humidity tends to be generally lower, due to the reduced capacity of soil evapotranspiration, the limited presence of vegetation, and the rapid dispersion of rainwater caused by the prevalence of impermeable surfaces[15].

*Earth Surface Energy Balance*
These three components give rise to the surface energy balance equation:

$$R + A + D + L + C + P = 0$$

Where

13 *Ivi*, pp. 32-34.
14 Valid for neutral atmospheric stability; requires z > d.
15 *Ivi*, pp. 35-38.





R: Radiative balance, i.e. the difference between the incoming and outgoing energy at the Earth's surface in the form of radiation
A: Vertical convective heat flux associated with ventilation: if positive, supplies heat to the ground; if negative, removes it
D: Advection, i.e. the horizontal convective heat flux associated with ventilation
L: Latent heat flux exchanged with the ground and associated with the processes of evaporation and condensation of atmospheric moisture: if positive, it indicates evaporation; if negative, it indicates condensation
C: Heat flux by conduction through the ground, or by convection in the case of water surfaces: if positive, heat is transferred from the surface to the atmospheric layer; if negative, it flows into the subsurface
P: Heat flux due to atmospheric precipitation on the Earth's surface
Overall, the contribution of the radiative balance is usually predominant compared to the other terms, while conduction and convection play a minor role, generally accounting for only about 2% of the total balance[16].

### 4.1.3 The Urban Heat Island Phenomenon (UHI)

The urban heat island (UHI) is a specific and localised microclimatic regime that develops in correspondence with an urban agglomeration, clearly distinguishing itself from the surrounding context, which is characterised by a different and more uniform thermal-climatic system[17]. Temperature differences between urban areas and adjacent rural zones can range from 1.5°C up to 5.5°C[18]. Although the phenomenon had already been observed in ancient times, as early as the Roman era[19], the first to formalise the concept of the UHI was Luke Howard at the beginning of the nineteenth century[20]. Subsequently, the phenomenon has been studied, analysed, and documented by numerous scholars in different cities[21].
As summarised in Figures 59 and 60, permeable vegetated areas tend to retain moisture and promote higher near ground humidity through evapotranspiration and shading, whereas sealed artificial surfaces limit moisture exchange and can heat up rapidly under solar exposure. The main factors contributing to the formation of the UHI include: the increase in longwave infrared radiative flux from the sky, linked to the presence of atmospheric pollutants over urban areas; the greater absorption of solar radiation due to the extensive

16 *Ivi*, p. 39.
17 D'Olimpio 2008, p. 41.
18 *Ivi*, p. 42.
19 Horace 1998; Seneca 2006. Horace and Seneca, in their writings, refer to the greater 'heaviness' of urban air compared to that of rural areas.
20 Howard 1833.
21 Chandler 1970; Chandler 1976; Oke 1974; Oke 1979.

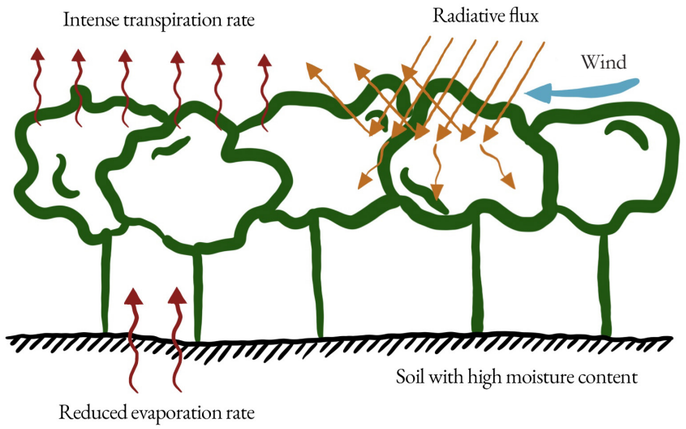



**Fig. 59**
*Microclimatic behavior of vegetated areas. The soil in these areas is permeable and capable of retaining moisture, also thanks to the action of vegetation, which promotes high levels of air humidity. The presence of trees contributes to shading and to the reduction of ventilation, thereby reinforcing such microclimatic conditions. Source: author's graphic elaboration from D'Olimpo 2008, p. 38.*

exposed surfaces (not only the ground, but also walls and roofs); the continuous radiative exchanges between buildings in urban canyons[22], which reduce the dispersion of longwave thermal radiation because of the limited sky view factor; the high thermal capacity of construction materials, which favors heat storage; the reduced soil evapotranspiration, caused by the use of impervious materials and the limited presence of green surfaces; the decrease in convective heat dispersion, due to poor ventilation resulting from the high roughness coefficient of urban environments[23]; and finally, the emission of anthropogenic thermal radiation generated by activities such as energy production in buildings, vehicular traffic, and industrial processes[24]. On cloudy and windy days, the intensity of the heat island tends to decrease and microclimatic conditions approach those of the macroclimate. Conversely, on sunny and poorly ventilated days, the phenomenon intensifies[25].
Within the UHI, air temperatures are not constant but heterogeneous, being primarily influenced by urban morphology, the construction characteristics of buildings, building density, and the presence or absence of vegetation in a specific point. The amount of re-radiated thermal energy varies according to urban form, particularly the height-to-distance ratios between buildings, and building density, which represent key variables in the reflection and absorption of solar radiation. Albedo also plays a crucial role in this dynamic and must be taken into account[26].

22 Rose, Devadas 2007, p. 215. The urban street canyons are particularly influencing elements, intended as "*the open spaces between buildings, having various microclimates. A dense urban fabric may provide solar shading to pedestrians within deep street canyons; on the other hand they may also become "heat traps" due to reflection and reduced albedo, diminished night sky radiation and substantially reduced ventilation*".

23 D'Olimpio 2008, pp. 42-43.

24 Chrysoulakis, Grimmond 2016.

25 D'Olimpio 2008, p. 43.

26 *Ivi*, pp. 57-58.





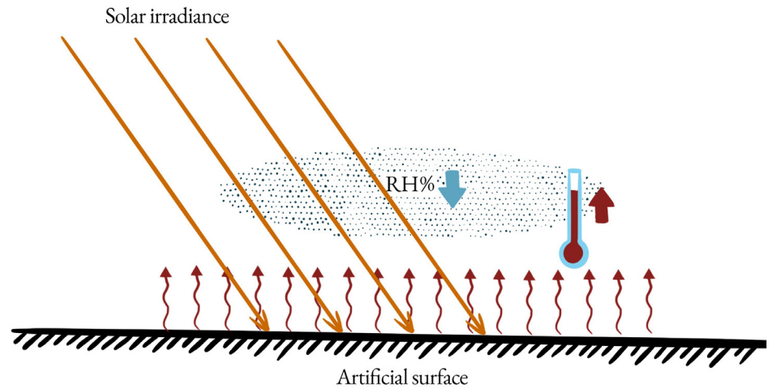



**Fig. 60**
*Microclimatic behavior of artificial surfaces. These areas, by not absorbing rainwater, contribute to reduced relative humidity. On sunny days, they heat up rapidly, thereby accentuating the phenomenon. Source: author's graphic elaboration from D'Olimpo 2008, p. 37.*

Numerous studies have demonstrated that the size of the settlement influences the intensity of the UHI and should be a factor to be considered[27]. However, the configuration of the built environment also influences the phenomenon: elongated or dispersed cities tend to exhibit lower UHI intensities, whereas compact cities developed around a central core generally display higher UHI intensities[28]. Nevertheless, these considerations must be contextualised with other factors, such as the increased anthropogenic heat and $CO_2$ emissions that a dispersed city may generate, or the negative impact of urban sprawl on land consumption. In conclusion, such recommendations should always be adapted to regional specificities[29].
Moreover, the UHI influences meteorological phenomena, both with respect to the layer directly affecting the urban area (urban canopy layer) and to the overlying layer (urban boundary layer) (Fig. 61). It can, for instance, lead to increased precipitation and thunderstorms, caused by the condensation of warm air masses generated by the re-radiation of thermal energy accumulated in anthropogenic materials used in urban settlements. This process induces upward air motions which, in the presence of humidity, give rise to cloud formation[30]. Another phenomenon associated with the urban heat island is the occurrence of air flows from rural areas toward urban ones, driven by temperature differences[31].
Finally, it is important to mention the influence that the UHI can have on human health, especially when combined with other phenomena such as heat waves. The groups most exposed to risks are clearly the most vulnerable categories, such as the elderly and individuals with pre-existing health conditions. The consequences may range from hospitalization to death[32].

27 e.g. Oke 1973; Zhou *et al.* 2017.

28 Zhou *et al.* 2017, pp. 6-7.

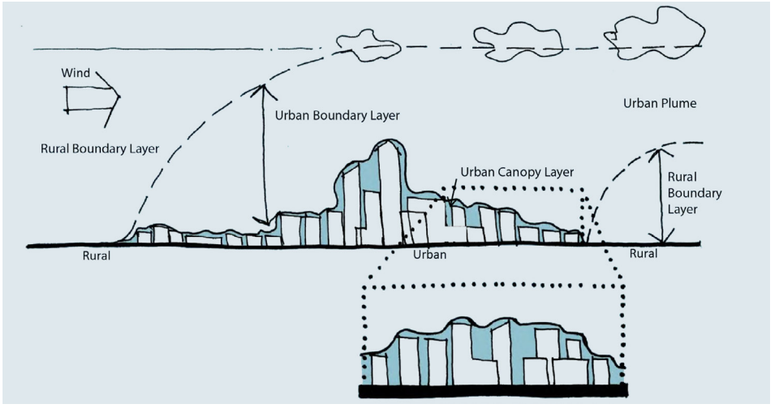
29 *Ivi*, p. 7.

30 D'Olimpio 2008, pp. 46-49.

31 Collo 1986.

32 Heaviside *et al.* 2017, pp. 30-31.

**Fig. 61**
*Urban boundary layer and urban canopy layer. Source: Hong Kong Green Building Council 2017, p. 4.*




### 4.1.4 Thermo-hygrometric comfort

Human energy largely depends on the environmental conditions in which individuals are situated. For example, in regions characterised by extremely high or low temperatures, a significant portion of the body's energy is directed toward adapting to climatic conditions, thereby reducing the amount available for other activities[33]. One of the earliest in-depth studies on these issues is that of Huntington, who highlighted the correlation between human productivity and particularly hot atmospheric conditions in the northeastern United States. In the same research, the results were compared with several European regions: in high-latitude areas such as the Scandinavian countries or Scotland, the summer season proved to be the most favorable for productivity; in Mediterranean nations such as Italy, Spain, or Greece, by contrast, the summer season was considered less favorable than the winter; and in the southernmost Mediterranean areas, winter conditions were found to be the most advantageous[34]. Huntington's study thus underscores that human beings are able to perform at their maximum capacity only within certain limits, which correspond to the most favorable climatic conditions[35].
Thermo-hygrometric comfort of the individual can be defined as the mental condition of satisfaction with the thermal environment, which corresponds to the state in which the subject feels neither hot nor cold[36]. Alternatively, it can be referred to as the point at which the body, in adapting to environmental conditions, expends the minimum amount of energy[37]. Indeed, the human body and its metabolic processes constantly produce heat, which must be dissipated into the environment in order to prevent an

33 Olgyay 1981, p. 29.
34 Huntington 1930.
35 Olgyay 1981, pp. 29-30.
36 International Organization for Standardization 2005.
37 Olgyay 1981, p. 31.





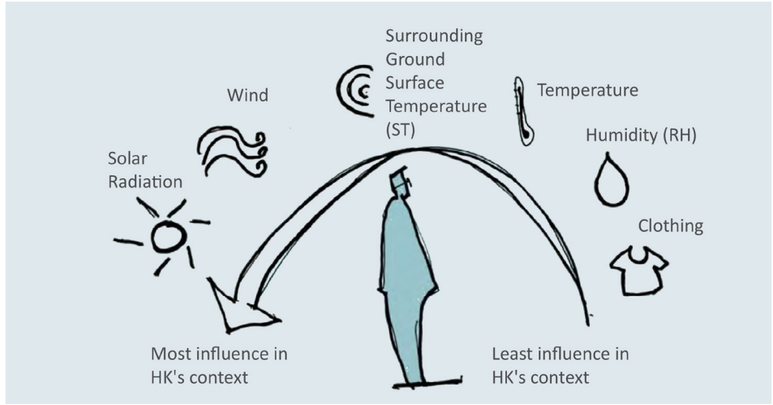



**Fig. 62**
*Factors influencing thermal comfort. Source: Hong Kong Green Building Council 2017, p. 8.*

excessive increase in internal body temperature[38]. The factors influencing human thermo-hygrometric comfort may be environmental, such as air temperature, air movement, humidity, and solar radiation, or subjective, such as the level of activity (and consequently the metabolic rate), the type of clothing worn, health status, and acclimatisation (which occurs when the body gradually adapts to specific conditions). Other interfering factors are related to subcutaneous fat, age and gender, physical fitness, as well as food and beverages consumed, which can influence metabolism[39].
The range encompassing acceptable conditions is generally referred to as the comfort zone, defined by ASHRAE as the combination of air temperature, mean radiant temperature, and humidity that is expected to constitute a thermally acceptable environment for specified values of air velocity, metabolic rate, and clothing insulation[40]. Since thermo-hygrometric comfort is influenced by three additional environmental variables beyond air temperature alone, identifying an index capable of capturing its complexity was not immediate (Fig. 62). Several attempts were made from the early decades of the twentieth century: the first dates back to 1923, when Houghten and Yagloglou introduced the concept of "effective temperature" (ET), with the aim of recognising the influence of humidity on thermal perception[41]. This system, accompanied by a derived chart, was widely used not only to define standards[42] but also as a starting point for further studies[43]. One such study was conducted by Victor Olgyay, who introduced the bioclimatic chart, representing air temperature on the horizontal axis and relative humidity on

38 Szokolay 2004, pp. 16-17.
39 *Ivi*, pp. 17-19.
40 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 2020.
41 Houghton, Yaglou 1923.
42 ASHRAE 1995.
43 Bedford 1936; Givoni 1969; Koenigsberger *et al.* 1973; Vernon, Warner 1932.

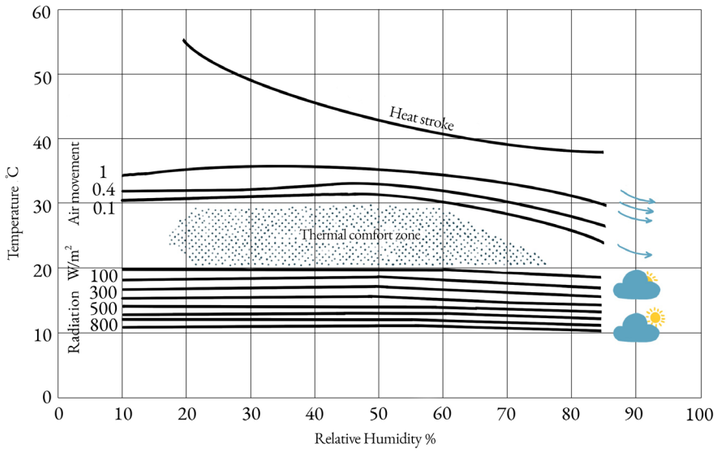



**Fig. 63**
*Olgyay's Bioclimatic chart. Source: author's graphic elaboration from Olgyay 1981, p. 44.*

the vertical axis (Fig. 63). At its center, the "comfort zone" is delineated, whose upper and lower limits can be extended by the presence of ventilation or solar radiation[44]. The chart was constructed by Olgyay using previously published data, statistically derived from earlier empirical studies[45].
Since then, approximately one hundred comfort indices have been proposed, each developed according to different theoretical and empirical approaches, with varying formulas, criteria, and designations, most of which are primarily applied to indoor environments[46]. Among the most widely used for outdoor microclimates are the PMV (Predicted Mean Vote), resulting from the experiments conducted by the Danish researcher P. Ole Fanger[47], followed by the SET* (Standard Effective Temperature)[48], PET (Physiologically Equivalent Temperature)[49], OUT_SET* (Outdoor Standard Effective Temperature)[50], and UTCI (Universal Thermal Climate Index)[51]. One of the main difficulties in the field of outdoor comfort studies is the low degree of standardisation, caused by the heterogeneity of the indices and of their application, which hinder the possibility of carrying out consistent quantitative comparisons[52].

44 Olgyay 1981, pp. 35-46.

45 Shanthi Priya *et al.* 2012, pp. 544-545. For example, the studies of the British Department of Scientific and Industrial Research, directed by Vernon and Beldford, in which Vernon stated that the ideal temperature with slight air movement (0.25 m/s or less) is 18.9 °C in summer and 16.7 °C in winter, or the studies of Markham, who proposed as an ideal zone a temperature range between 15.6 and 24.4 °C with midday relative humidity varying between 40 and 70%.

46 Szokolay 2004, p. 21; Shooshtarian *et al.* 2020, p. 2.

47 Ole Fanger 1972.

48 Gagge *et al.* 1972.

49 Based on Höppe 1993.

50 Pickup, de Dear 2000.

51 Bröde *et al.* 2012.

52 Liu *et al.* 2022.





## 4.2 Towards an Integrated Approach to the Historic Urban Fabric: the Microclimate and Outdoor Thermal Comfort Research Field

Although sustainability is affirmed in policy and practise, implementation is shaped by constraints such as budgeting cycles, institutional routines, limited time, and uneven technical capacity within local administrations. In small historic centres, these conditions can favour piecemeal decisions in public space and maintenance, where lowest-cost compliance may override design quality, not necessarily due to wrong intentions but to the absence of a framework capable of reading the settlement as an integrated system and anticipating cumulative effects[53].
In the absence of a comprehensive legislative and operative framework, recurrent tendencies include the widespread use of industrial materials, informal or ad hoc self-building practices, and the growing reliance on mechanical heating, ventilation, and air conditioning (HVAC) systems[54]. Their effects are not uniform: they can be beneficial in some circumstances, yet they may become problematic when introduced without a diagnostic understanding of local microclimatic behaviour and without compatibility checks with the material and spatial logic of the historic fabric[55]. The accumulation of small, uncoordinated changes may contribute to two coupled outcomes: reduced outdoor thermal liveability and a gradual loss of landscape and fabric coherence through the erosion of vernacular constructive logics and material continuity.
These pressures are intensified by climate change, which can reduce the usability of open spaces that have historically supported everyday sociability and local routines, especially in villages where public space functions as a key social asset. Decision-making in minor historic towns is often compressed by emergency logics, fragmented funding, and deadlines that constrain design, while action can be hindered either by treating historic settlements as enclaves of fixed authenticity or by applying generic technical templates that overlook local morphology, materials, and heritage values. In conservation processes, innovation is therefore better framed not as a discretionary add-on, but as a means to reconcile continuity of significance with contemporary liveability, provided that it is grounded in contextual diagnosis and evaluated against both environmental and heritage criteria[56].
A further limitation of current practice is scale. Many guidelines and design activities related to energy still focus on the individual building, yet in historic settlements meaning and performance are inseparable from the aggregate[57]. This emphasis on the settlement scale reflects the understanding of historic

53 Fila *et al.* 2024.

54 Cremaschi 1990; Hammond, Jones 2008; Salamanca *et al.* 2014.

55 Lidelöw *et al.* 2019; Buda *et al.* 2021; Gori *et al.* 2021.

56 Spanedda 2007b, pp. 10-11; Cirasa 2011, pp. 16-17.

57 De Pascali 2008; Chiri *et al.* 2020, p. 1.

villages as socio-spatial systems introduced in Chapter 1, rather than as a collection of isolated buildings. Moreover, the fabric is defined not only by specialised monuments, but by the relationships that bind its parts into a single organism, so energy exchanges cannot be understood by isolating technological components alone.

"*A significant share of energy is, in fact, linked to the physical and functional relationships which are established, or may be established, among the various elements of the settlement, and which determine the city's shape and organization*"[58].

The feedback interaction between urban context and local microclimate can influence building energy use, peak loads, indoor environmental quality, and outdoor heat rejection. Targeting the outdoor microclimate can therefore generate benefits at both urban and building scales[59]. In particular, the relationship between surrounding context and individual buildings is shaped by conditions that include local temperature regimes and heat accumulation relative to the mesoclimate[60], urban morphology and orientation[61], contextual materials and albedo[62], and vegetation and evapotranspiration[63].
Hence, care for a single unit cannot ignore the overall settlement volume and its relational structure. This is the sense of an integrated and ecological vision of conservation: identity is maintained through a comprehensive approach that reconciles continuity with change across the entirety of the fabric[64]. Energy policy should follow suit, because guidance that focuses only on the single building delivers diminishing returns when the settlement is treated as a set of isolated units[65]. In this respect, urban microclimate and outdoor thermal comfort assessment, conducted in parallel with an evaluation of historical, architectural, and landscape values, offers a coherent way forward[66]. It makes interactions between elements explicit and allows the collective performance of the historic fabric to be described, tested, and translated into design and planning decisions.

58 *Ivi* (cited by Chiri *et al.* 2020, p. 1).
59 Ratti *et al.* 2005.
60 e.g. Taha 1997.
61 e.g. Salamanca *et al.* 2010.
62 e.g. Taha 1997.
63 e.g. Vu *et al.* 1998
64 Vitiello 2012.
65 De Pascali 2008; Chiri et al. 2020; Vitiello 2023, pp. 5-7.
66 Giusti 2012, p. 90.





### 4.2.1 Outdoor Microclimate Assessment in Existing and Historic Urban Contexts: A Literature Review on Influencing Factors

Outdoor thermal comfort (OTC) underpins the liveability and vitality of urban space, used and valued in relation to their visual quality, functional suitability, and environmental comfort[67]. Neglecting climate priorities in urban studies can undermine OTC and public health. For this reason, many researchers assess microclimate, thermal discomfort, and heat stres in different settings[68]. Several studies concentrate on existing urban environments, highlighting the link between the geometry of urban spaces and local microclimate. A study in Santiago de Chile systematically modelled different urban canyon layouts and found strong effects of orientation and canyon depth: east–west oriented streets, which receive long solar exposure, had the highest thermal discomfort during summer, whereas north–south streets were much cooler. It also showed that deeper canyons, with higher height-to-width (H/W) ratio, improve shading: narrow, tall streets remain cooler by day[69]. This is closely related to the notion of the sky view factor (SVF), the fraction of the sky hemisphere visible from a point within the street canyon. SVF ranges from 0, where the sky is completely obscured by surrounding façades and overhangs, to 1, where the point is fully exposed to an unobstructed sky. In radiative terms, SVF is the proportion of long-wave or short-wave exchange between a planar surface and the sky relative to exchange with the entire hemispherical environment. Taller enclosing buildings reduce sky visibility and thus lower SVF, while shorter buildings or wider streets increase it[70] (Fig. 64).
These results mirror findings in other climates: for example, a hot Mediterranean study similarly found E–W canyons most uncomfortable and that higher aspect ratio yields greater summer shade. In contrast, wide open streets (low height-to-width ratio) heat up quickly[71]. Moreover, shading by adjacent buildings significantly lowers ambient air temperature during the day. By contrast, they note that stored heat in building mass and pavements drives up night-time UHI, so dense canyons can trap warmth after sunset[72]. Thus, high density and compact form, such as those commonly found in temperate climates, can increase heat retention in the urban fabric, particularly at night. Yet, street orientation and geometry strongly modulate solar access and airflow, enhancing adaptability and improving thermal performance across seasons.

67 Soares *et al.* 2021, p. 3.
68 Aghamolaei *et al.* 2023, p. 2204.
69 Cárdenas-Jirón *et al.* 2023.
70 Dirksena *et al.* 2019; Miao *et al.* 2020, p. 1. The concept of SVF was first introduced by Oke 1981 to assess the UHI effect on urban environments.
71 Achour-Younsi, Kharrat 2015.
72 Tong *et al.* 2017. We can say that radiant heat is "the main contributor" to night-time UHI.

Furthermore, urban surface properties modulate short- and long-wave exchanges and heat storage, with mixed outcomes for outdoor conditions. For albedo, field and modelling studies show daytime reductions in surface temperature and sometimes air temperature, yet they also warn that extra reflected short-wave can raise mean radiant temperature (MRT) at pedestrian level in sun-exposed canyons. Studies demonstrate that, although high-albedo materials can slightly reduce air temperature, it impacts mean radiant temperature, which dominates outdoor thermal comfort increasing pedestrian radiant load and heat stress in street canyons; in shade-limited canyons, increased reflections can raise MRT and worsen comfort, so net benefits depend on shading and geometry[73]. For this purpose, the Solar Reflectance Index (SRI) can be a useful parameter, and is already included in the technical data sheets of some products[74]. The SRI combines solar reflectance and thermal emissivity into a single indicator that expresses how hot a surface is likely to become under solar radiation, with higher values indicating that the material reflects more solar energy and remains cooler[75].

With respect to thermal inertia, research confirms that high-capacity materials store heat by day and release it after sunset, sustaining nocturnal warmth; this is amplified where the SVF is low and long-wave cooling to the sky is restricted[76]. Conversely, permeable and moisture-retentive pavements can promote evaporative cooling and reduce surface temperature and near-surface air temperature when water is available, although performance varies with hydraulic design and climate. Laboratory and field evidence in southern China documents meaningful evaporative cooling from permeable pavements, and neighbourhood-scale simulations show that permeable and reflective pavements can lower surface and near-surface temperatures, with magnitudes sensitive to construction type and boundary conditions[77].

In summary, key morphological factors of the built environment identified in the literature include street orientation; urban canyon aspect ratio (H/W); density and SVF; materials and surfaces.

In historic urban settings, such considerations are extremely useful: by examining a given context, its operative functioning and the underlying climatic and thermal rationales that shaped its development can be evaluated through these principles. The resulting insights also imply that each block or square may respond differently depending on its configuration, reinforcing the need for context-aware analysis. Indeed, these topics have been examined

73 e.g. Erell *et al.* 2014; Schrijvers *et al.* 2016.

74 Especially natural (stone) and artificial (cement) pavements, reflective coatings, and roof membranes.

75 e.g. Jandaghian *et al.* 2025.

76 For example, Bernabé *et al.* (2015) highlight the role of radiative trapping and storage in shaping the UHI, while Mandanici *et al.* (2024) links higher roofing thermal inertia to stronger night-time surface UHI intensity.

77 Wang *et al.* 2018; Ferrari *et al.* 2019; Ferrari *et al.* 2020.





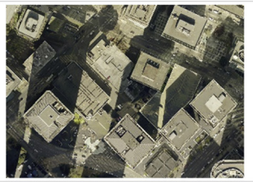
| LCZs | Site Photographs | | Site properties | LCZ schematics |
|---|---|---|---|---|
| | Aerial view | Sky view | | |
| LCZ 1 |  |  | **SVF 0.2**<br>**% built-up >95** |  <br>Compact highrise |
| LCZ 4 |  |  | **SVF 0.5**<br>**% built-up >80** |  <br>Open highrise |
| LCZ 5 |  |  | **SVF 0.55**<br>**% built-up >85** |  <br>Open midrise |
| LCZ 6 |  |  | **SVF 0.75**<br>**% built-up >45-55** |  <br>Open lowrise |
| LCZ 6A |  |  | **SVF 0.7**<br>**% built-up >40-50** |  <br>Open lowrise (dense trees) |
| LCZ 8 |  |  | **SVF 0.77**<br>**% built-up >95** |  <br>Large lowrise |

**Fig. 64**
*Sky view of different urban configurations in Vancouver. Source: Aminipouri et al. 2019, p. 11.*

by many studies, building on a longer tradition of bioclimatic inquiry into vernacular architecture, which has highlighted how traditional spatial forms and passive strategies influence thermal behaviour and can inform sustainable design today[78].

As previously mentioned, the proximity to vegetation and water also have an influence on the microclimate. Consistent park and tree cooling is reported in many studies, with "park cool island" magnitudes commonly ranging from 1.5 to 9.5 °C, and meta-analytic evidence that parks are on average about 1 °C cooler than nearby non-green sites. Moreover, façade-scale findings show that vertical greenery reduces surface temperatures by 1–15 °C in warm temperate climates[79]. As for water bodies, stronger daytime than night-time cooling is generally reported. The larger the share of water in an area, the stronger the cooling effect, although each extra increase in water area adds a smaller additional benefit than the previous one[80]. Complementing this, a study evaluate typical small urban water bodies in the Netherlands and find highly local and modest air-temperature effects: afternoon difference on air temperature is typically ~0.2 °C, with a maximum of 0.6 °C. They also note potential night-time warming when water remains warmer than air and emphasise the role of turbulence in the wind field in determining whether cooling is perceptible at pedestrian level[81].

Over the past decades, the urban microclimate field has broadened as methods are combined with urban design to support climate adaptation and wider climate action. On one hand, some studies focus on the relationship between microclimate and energy consumption: rising outdoor temperatures in settlements drive up cooling demand across clusters of buildings while heavy use of air conditioning in summer can itself intensify the urban heat island (UHI), raising peak electricity demand by 5–10%[82]. These findings illustrate a vicious cycle: warmer cities require more cooling, which then dumps waste heat back to the environment through outdoor units. "*The urban overheating phenomenon is becoming significant in cities, causing extreme weather conditions that negatively affect citizen comfort and health, and increase building energy consumption*"[83].

On the other hand, a large body of literature underscores the influence of climate change to deteriorating urban outdoor comfort, with phenomena such as the UHI, amplified by factors such as higher building density, which can hinder natural ventilation, impervious surfaces, which contribute to increased land surface temperature, and loss of green, which removes shading and evapotranspiration elevating surface and radiant temperatures with

78 e.g. Aronin 1953; Olgyay 1981; Tang *et al.* 2011; Manzano-Agugliaro *et al.* 2015; Desogus *et al.* 2016; Salata *et al.* 2016.

79 Bartesaghi Koc *et al.* 2018.

80 Cao *et al.* 2022.

81 Jacobs *et al.* 2020.

82 Ryu, Baik 2012; Salamanca *et al.*, 2014; Tong *et al.* 2017, p. 1.

83 Ascione *et al.* 2024, p. 1.





consequent heat stress and health risks[84]. Urban microclimate assessment approach has been therefore used by many studies to assess the impact of climate change on existing urban contexts and think of mitigating solutions[85]. This approach is defined in literature "climate-sensitive urban planning", understood as the integration of climate data into design to improve the lived climate[86]. An important critical vision that emerges is that strategies cannot be generalised: each city demands tailor-made solutions[87]. Thus, the microclimate approach could be essential for identifying how global climate trends play out locally and how we can respond to local needs.

In this direction, climate-sensitive research on heritage and historic settlements has grown steadily in recent years, reflecting greater recognition of climate risks to cultural assets and vulnerable settings. Nonetheless, it remains limited and focused on clusters of buildings, neighborhoods, or public space systems, rather than the entirety of the urban area[88]. Indeed, historic urban spaces are complex environments to analyse as they impose constraints: narrow streets, fixed building form, and listed areas. A study in two squares in Seville's old town investigates thermal discomfort exacerbated by UHI. The traditional fabric is made up of dense mass-brick walls and the studied areas are characterised by a lack of vegetation, shading, and water features, as it is typical in traditional historical urban fabrics. Moreover, some of the materic features, in this case old ceramic-tile roofs and cobblestone pavements, dictate thermal behavior limiting natural cooling, but can't be replaced due to their heritage value[89]. A similar study, conducted in Florence specified how the primary aim of a microclimate mitigation action should be to "*avoid significative alterations of the integrity and authenticity of the built environment*"[90]. In this regard, many scholars emphasise that interventions "*must take these problematic considerations into account*"[91] and preserve the cultural heritage while enhancing their climate resilience[92]. Similarly, a vaste literature review point to a lack of local design models, especially pertinent in heritage contexts where generic measures may clash with preservation goals[93]. It also points out that OTC research has been concentrated in certain climates: temperate oceanic (Cfb), hot-summer Mediterranean (Csa) and humid subtropical (Cfa). However, despite being 40 of 173 case studies in their review in Csa climate, reflecting growing concern on the Mediterranean area as a hotspot for climate change, very few were

84 e.g. Oke 1988; Taha 1997; Haselbach *et al.* 2011; Santamouris *et al.* 2011; Sun, Chen 2017.

85 e.g. Tumini, Rubio-Bellido 2016; Pokrývková *et al.* 2021; Ascione *et al.* 2024.

86 Ren, Mc Gregor 2021; Cárdenas-Jirón *et al.* 2023 , p. 2.

87 Ascione *et al.* 2024, p. 1.

88 e.g. Ciacci *et al.* 2025; Rezaie *et al.* 2025; Wang *et. al* 2025b.

89 Rezaie *et al.* 2025.

90 Ciacci *et al.* 2025, p. 7.

91 Rezaie *et al.* 2025, p. 4.

92 *Ivi*, p. 23.

93 Mandic *et al.* 2024.

dedicated to historic urban environments[94].
Furthermore, although much research on microclimate has focused on mostly urbanised areas and large cities, rural regions also require attention (Fig. 65)[95]. In countries where rural and natural areas are being modified and urbanised more rapidly, such as China, research has grown on the impacts of the expansion on outdoor microclimate in rural traditional settlements[96]. One of the studies recognises that:

"*how to protect and inherit the cultural heritage in ancient villages furthest, and improve the public space effectively to achieve integration, symbiosis and sustainable development between urban and rural areas, has become an urgent problem to be solved*"[97].

This type of assessments are also being conceived as an opportunity for optimising land use, mediating the living environment, and promoting revitalisation especially in public spaces, the most used by residents and tourists in small historical villages[98].In the Mediterranean area, systematic work on outdoor microclimate assessment in historic villages is still at a nascent stage and the evidence base is thin[99].
Overall, the literature supports a detailed, context-aware approach to outdoor comfort that bridges climate science, urban design, and heritage conservation, highlighting the need for integrated visions, particularly in historic Mediterranean cities where liveability opportunities coexist with dense form and preservation constraints.

94 *Ibidem*.
95 Lyu *et al.* 2024, p. 1:Roy *et al.* 2025, p. 2.
96 e.g. Xin *et al.* 2022; Lyu *et al.* 2024; Wan *et al.* 2025.
97 Xi *et al.* 2019, p. 1.
98 Xiao *et al.* 2023, p. 1.
99 One of the few examples of these studies is Soares *et al.* 2021.

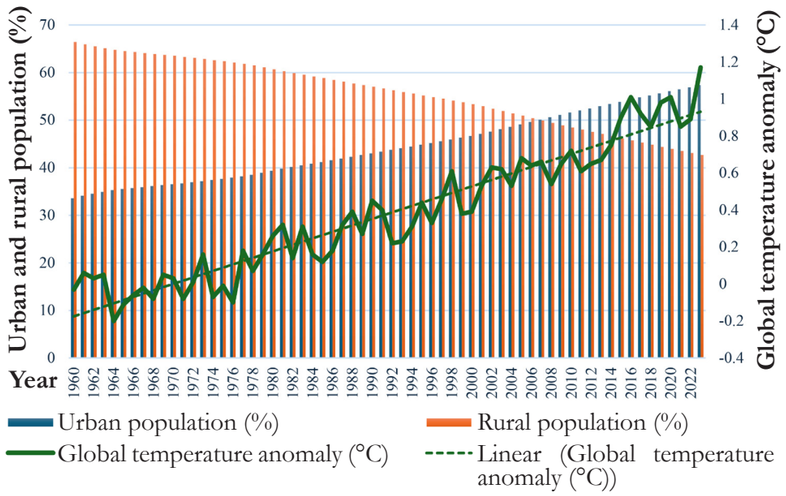



**Fig. 65**
*Urban and rural population (%) and global temperature anomaly (°C) from 1960 to 2023. Source: Graphic elaboration by Roy et al. 2025, p.2; data from World Bank and NASA Earth Observatory.*





### 4.2.2. Guidelines for Urban Microclimate and Planning: Pioneering Examples Worldwide

In recent years, several global cities and nations have adopted regulatory, guidelines, and planning tools to address the growing challenges posed by climate change on urban microclimates, Although most of them concern new construction activities in existing cities, they offer valuable insights on how to respond to the emerging need to integrate microclimate guidelines with urban planning. Among the most advanced examples is the City of London, which, since 2017, has developed a pioneering set of indications specifically dedicated to wind (Fig. 66) and thermal comfort, aiming to holistically evaluate the impacts of new developments on the microclimatic quality of public spaces. These guidelines, informed by scientific collaboration and simulation-based methodologies (e.g., Computational Fluid Dynamics modelling), integrate thermal comfort with solar, wind and humidity data, using the UTCI index as a predictive metric. They are not only evaluative but proactive: they aim to shape design decisions regarding the placement of parks, public seating, tree planting, and façade materials to enhance pedestrian comfort. The City of London positions microclimate control within its broader strategic planning documents, such as the London Plan and the Local Plan[100]. The promotion of this integrative and anticipatory approach has been driven by the negative impacts that certain towers and high-rise buildings have had on the usability and safety of public spaces. A well-known example is the "Walkie-Talkie" building at 20 Fenchurch Street, which became notorious after its highly reflective façade materials caused a safety hazard by concentrating sunlight to the extent that parts of a car parked nearby began to melt[101]. This incident prompted more comprehensive safety assessments of how proposed structures might affect conditions at street level. As a result, in London, microclimate guidance is now embedded in the development control process: the Wind Microclimate Guidelines and the Thermal Comfort Guidelines set out minimum study methods and reporting for planning applications, moving from generic advice to simulation-based assessments[102].
Germany, although lacking binding national microclimatic standards, mandates climate adaptation planning at the federal level[103]. The German Environment Agency (UBA) supports this obligation through technical guidelines that encourage the use of urban climate function maps, thermal load analyses, and air exchange corridor identification[104]. In Berlin, the Biotope Area Factor (BAF), introduced in 1994, serves as a legally binding environmental

100 City of London 2020; Danks *et al.* 2021.
101 BBC 2013.
102 City of London 2019; City of London 2020.
103 Federal Republic of Germany 2024.
104 Jacobi *et al.* 2024.

performance index in certain districts. By requiring a minimum proportion of ecologically effective surfaces in new developments, the BAF contributes to heat reduction, runoff control, and improved air quality. The flexibility of the BAF has facilitated widespread acceptance among developers, although its uneven implementation across districts due to administrative fragmentation underscores the need for stronger regional coordination. Despite this, it remains a compelling example of how quantified green infrastructure targets can be incorporated into local land-use planning[105]. Germany provides a model of law-backed climate planning. The Federal Building Code (BauGB) mandates that land-use planning incorporate environmental considerations and adaptation, and national agencies complement this with practical guidance for municipal risk, vulnerability, and urban-climate studies.

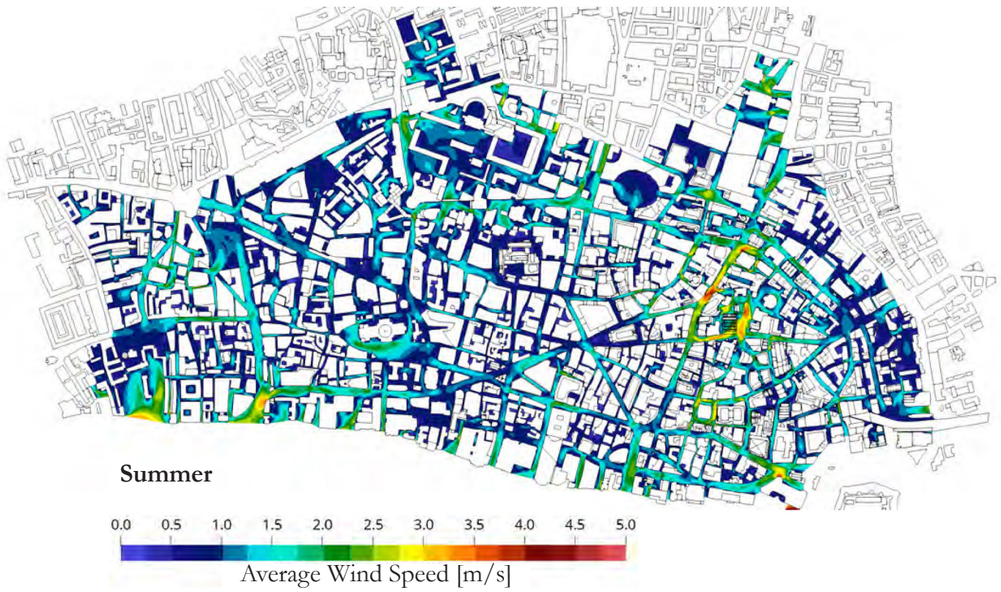
Vienna presents a well-structured case of integration of urban climate analysis into planning (Fig. 67). The *Stadtklimaanalyse* (Urban Climate Analysis), developed according to *Verein Deutscher Ingenieure* (Association of German Engineers) guidelines, identifies ventilation corridors and heat stress zones and functions as a prerequisite for project approval. Although not a binding legal tool, it is enforced through internal procedures by planning departments[106]. The 2035 Urban Development Plan and the Urban Heat Island Strategy embed microclimate mitigation into strategic environmental assessments and zoning, encouraging green roofs, tree planting, shading, and

**Fig. 66**
*London wind map in summer. used to identify pedestrian discomfort hotspots and inform development-control requirements Source: City of London 2020, pp. 8-9.*

**Fig. 67 (next page)**
*Vienna climate analysis map. Source: City of Vienna 2020-2021.*

105 Climate ADAPT 2020.

106 City of Vienna 2023a. The planning departments in Vienna are MA18 and MA22.








passive cooling[107]. Numeric simulation tools like ENVI-met support evidence-based planning[108]. Vienna's approach reflects how soft planning instruments, when consistently operationalised through institutional procedures, can have effects as strong as binding regulations: among all Austrian provinces, Vienna has by far the lowest amount of sealed surface per person, just 79.3 square meters per inhabitant, compared to the national average of 330.1 square meters[109].

In Portugal, early attempts to integrate climate data into master plans were largely ineffective due to inappropriate data scales and lack of technical expertise. Subsequent work in Lisbon, however, has marked a shift. The city has been divided into homogeneous climatic units to guide planning decisions on ventilation corridors, green infrastructure, and built density[110]. Though these guidelines are not mandatory, national Law 98/2021 now requires municipalities to progressively integrate climate-sensitive measures into local planning[111]. Therefore, any urban planning (e.g., master plans, zoning, local development rules) must include climate-sensitive measures to comply[112]. Porto's Municipal Climate Action Plan stands out for prioritising

107 City of Vienna 2018; City of Vienna 2025.

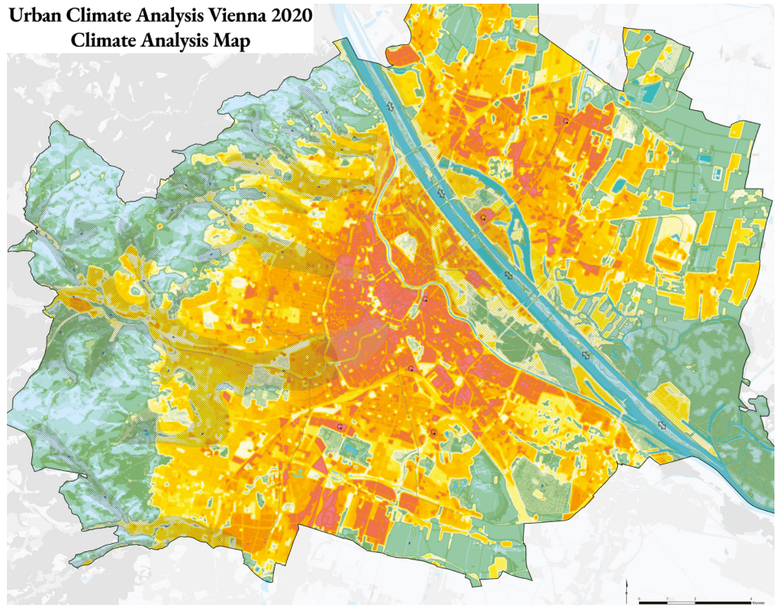
108 City of Vienna 2018.

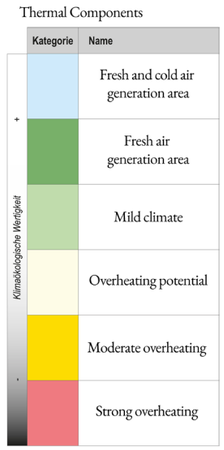
109 Environment Agency Austria 2023; City of Vienna 2023b; ÖROK 2023.

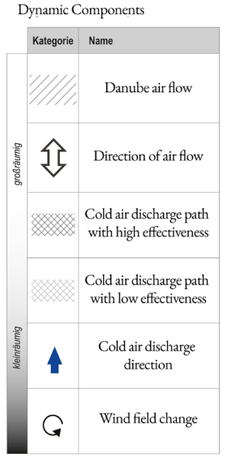
110 Alcoforado *et al.* 2009.

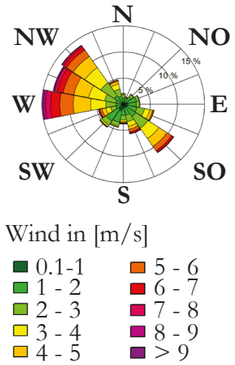
111 Portuguese Republic 2024, art. 14.

112 *Ivi*, art. 11.



thermal comfort in both public and private built environments, using maps of thermally critical areas to guide its adaptation strategies[113]. Yet, as of July 2025, only about 150 of 308 municipalities had published or were consulting a Municipal Climate Action Plan[114]. The lack of enforcement mechanisms and the partial implementation of local plans risk undermining the law's effectiveness.

In Hong Kong, the 2017 Guidebook on Urban Microclimate Study offers a technical framework for optimizing local climatic conditions. Developed collaboratively by government and institutions, it outlines methods for evaluating microclimate factors (e.g., wind, solar access, humidity) and integrating them into urban design. Though non-binding, it serves as an educational and operational resource for planners and developers, and encourages the adoption of climate-responsive building forms and open space configurations[115].

Australia has framed urban heat as a national adaptation priority. The National Climate Resilience and Adaptation Strategy 2021–2025 positions the country to "better anticipate, manage and adapt" to climate impacts, explicitly noting the need for action across governments, business and communities, including urban domains where heatwaves are intensifying and mitigation requires implementation, testing, and evaluation[116]. Building on this policy setting, research funded through the Cooperative Research Centre for Low Carbon Living (CRCLCL) developed two complementary decision-support

113 Municipality of Porto 2025, pp. 42-56, 209.

114 Cooler World 2025.

115 Hong Kong Green Building Council 2017.

116 Australian Government 2021, pp. 6-7, 12.

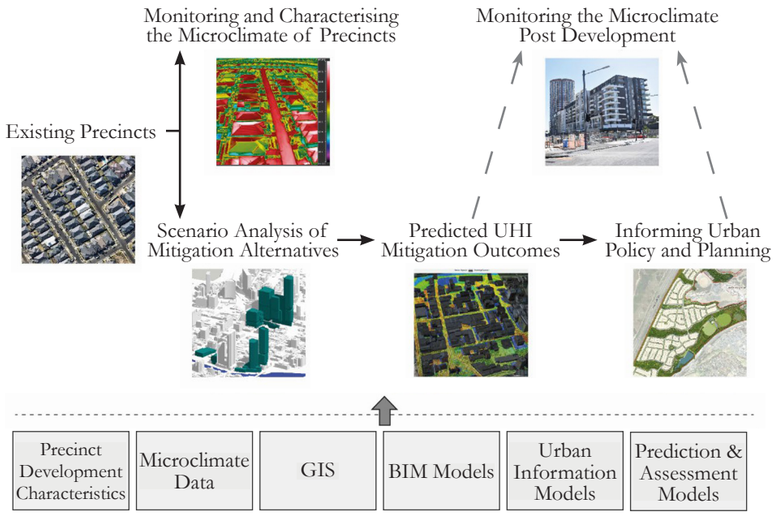



**Fig. 68**
*UHI-DS tool framework showing the workflow from input data and modelling to decision-support outputs for precinct-scale mitigation planning. Source: author's graphic elaboration from Ding et al. 2019, p. 7.*





instruments. First, the Microclimate and Urban Heat Island Decision-Support Tool (UHI-DS) integrates GIS and BIM data at building and precinct scales with microclimate simulation and surrogate models to assess scenarios, including outdoor thermal comfort and peak electricity demand outcomes (Fig. 68). Public materials describe its exemplar-precinct applications and workflow, and indicate restricted login access for operational use[117].

Second, the publicly accessible Urban Heat Island Mitigation Performance Index provides general advice by rating the expected suitability and effectiveness of 17 mitigating options for a user-selected objective, climate region and urban context, communicating likely performance of single measures and important combinations to inform planning and policy[118] (Fig. 69). These tools are embedded in a wider UNSW programme on urban overheating and cooling that translates evidence into guidance for precinct-scale interventions, for example the Guide to Urban Cooling Strategies, and are consistent with national efforts to coordinate adaptation and reduce heat vulnerability in Australian cities.

Across these contexts, a shared trend emerges: the gradual embedding of microclimatic considerations into planning practice, often propelled by soft tools (guidelines, strategies, handbooks) rather than strict legal requirements. Indeed, the most effective cases, such as London, Vienna, and Australia, demonstrate that the success of microclimate-responsive planning is less about the binding nature of instruments and more about their integration into urban governance and decision-making processes.

117 Ding *et al.* 2019, pp. 6-26.

118 Ding *et al.* 2019, pp. 26-30.

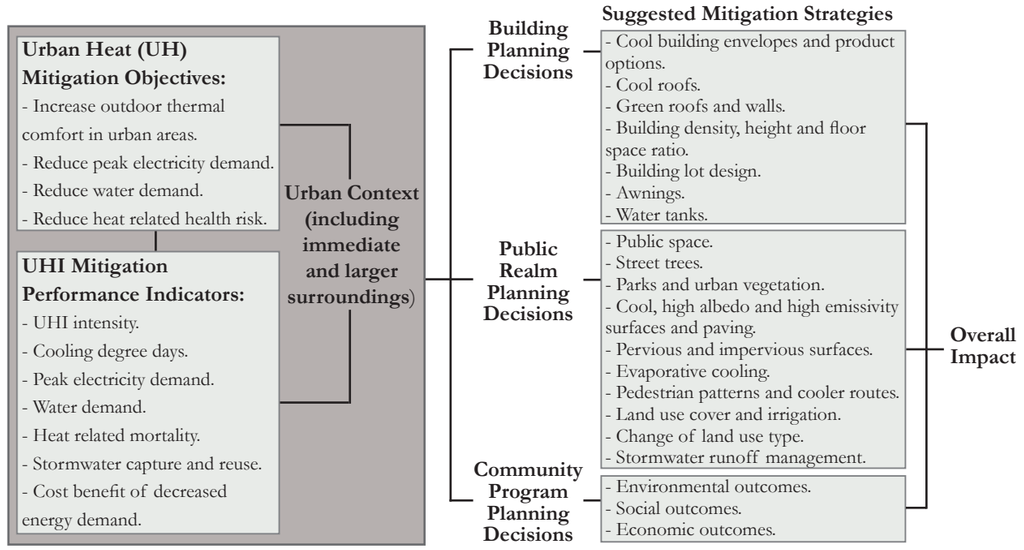



**Fig. 69**
*Structure of the UHI Mitigation Performance Index, illustrating how mitigation options are evaluated and compared across multiple criteria. Source: author's graphic elaboration from Ding et al. 2019, p. 27.*

## 4.3 The Urban Microclimate Design (UMD) for Heritage and Climate-Oriented Approaches

This study adopts an interdisciplinary approach that brings together heritage conservation and urban microclimate science. On the one hand, it is grounded in the restoration perspective, which prioritises the conservation of cultural significance, material authenticity, and the legibility of historic fabric. On the other, it mobilises microclimate and outdoor thermal comfort (OTC) assessment to enhance environmental performance in the public realm. The method is designed to hold these two lenses in productive tension, identifying climate-sensitive risks and opportunities while preserving heritage values within protection strategies for small rural settlements. The need for such an operational structure emerges directly from the gaps identified in Chapter 3 between regulatory ambitions and the lack of practical tools available to designers and local administrations.

The aim is twofold. First, to generate technical evidence that explains how climate change, urban morphology, materials, and vegetation shape local microclimates in heritage contexts. Second, to translate that evidence into clear, actionable guidance that local administrations in small historical settlements can embed in municipal planning and project briefs.

The approach recognises that findings are context dependent. Results reported here are calibrated for a specific Mediterranean climate and for the material and morphological features studied through the case-study settlement. The process is designed to be replicable elsewhere, provided that local characteristics and properties are re-specified.

Within the adopted framework, the conservation and microclimate perspectives are interwoven throughout the entire process, from the analytical phase to the design phase. The process has been developed from the Urban Microclimate Design (UMD) framework[119] originally articulated and commonly applied to planned interventions in contemporary cities, here adapted to the spatial, cultural, and regulatory specificities of small historic settlements.

The process begins with a knowledge phase that develops a fine-grained reading of urban and architectural characteristics, aimed at identifying values, constraints and vulnerabilities that shape the limits and opportunities of the conservation intervention. An in-depth diagnostic stage is a cornerstone of planned intervention: the more complex the context of action, the more critical and carefully calibrated the project must be[120].

From the information gathered through the knowledge phase, three-

119 Chiri *et al.* 2020.

120 From approaches directed to the monument, e.g. Gazzola *et al.* 1964, article 9, "*The restoration in any case must be preceded and followed by an archaeological and historical study of the monument*", to indications for interventions in urban contexts, e.g. ICOMOS 1987, point 5, "*Planning for the conservation of historic towns and urban areas should be preceded by multidisciplinary studies*" and "*Before any intervention, existing conditions in the area should be thoroughly documented*".





dimensional models are constructed for the urban configurations under examination. These may reproduce the present fabric or reconstruct past configurations of morphology and materials, depending on the study objective. Each model encodes the three dimensional street–block geometry, material properties of envelopes and ground surfaces, and vegetation in its spatial disposition and species mix; where topography exerts a significant influence near or within the settlement, a Digital Elevation Model (DEM) or Digital Terrain Model (DTM) is incorporated to represent slopes, ridges and valleys with sufficient fidelity.

These models provide the base for the microclimatic assessment through numerical simulations. The assessment is driven by local meteorological forcing (air temperature, humidity, wind speed and direction, and short-/long-wave radiation) derived from site stations, nearby observatories, or satellite data. Within this locally grounded frame, the effect of specific fabric elements, such as urban morphology (street proportions, building heights), surface materials, and planting on outdoor thermo-hygrometric conditions is tested. Because each historic settlement combines these controls differently, it is essential to establish which factors are most influential in that context. If the previous phase produced models for alternative configurations of the settlement or its parts (for example present and historical states), these can be subjected to comparative evaluation under consistent meteorological boundary conditions and performance metrics, so as to isolate the main drivers of change and to determine whether outdoor comfort has improved or deteriorated, and on what criteria. The assessment through simulation thus identifies the climatic and environmental components that most shape outdoor thermal comfort or discomfort, and in doing so informs the selection of the most effective, context-appropriate mitigating measures.

Mitigating solutions for improving outdoor thermal comfort can be geometrical, greening, evaporative cooling, and surface strategies. The most suitable approaches have to be selected taking into account a interdisciplinary evaluation, encompassing the historical, architectural, and landscape values, as well as opportunities and constraints for enhancement, identified in the first phase. This ensures not only that proposed actions do not jeopardise cultural heritage, but also that they target spaces with genuine potential for qualitative enhancement relative to their current condition. In depopulating contexts such as small historic villages in inner areas, this alignment is particularly important: well-placed, heritage-compatible measures can recover underused streets and squares and raise comfort levels in parts of the settlement that are underperforming due to heat stress or material decay.

The selected mitigating measures are then embedded in the previously developed models to generate alternative design scenarios. The microclimate assessment is repeated for each scenario to determine whether the proposed solutions are effective and to what extent. Results are appraised through a multi-criteria lens that considers, beside heritage compatibility, also long-term sustainability, implementation and maintenance costs, and impacts on

accessibility and patterns of use. If outcomes are unsatisfactory, the process returns to the option-selection stage, refining or recombining measures that are likely to yield better performance. This feedback loop continues until a configuration that delivers the desired effects is identified, and therefore can support the transition of the project from feasibility to detailed design. It should be noted that intervention is not always feasible in historic environments and, even when feasible, it may not be the most appropriate course; in some cases, refraining from intervention is preferable.
To summarise, the procedure can be articulated in the following steps:

**1.** Architectural and urban analysis of the current fabric, identifying cultural values, constraints, vulnerabilities, and opportunities for enhancement.

**2.** Selection of the meaningful configurations (urban morphology, materials, vegetation). These may represent present conditions or reconstructed historical states that are relevant to the research questions.

**3.** Development of three-dimensional models encoding street–block geometry, material properties, and vegetation layers. These provide the base for the microclimatic assessment.

**4.** Assessment of the urban microclimate through numerival simulations to characterise outdoor thermo-hygrometric performance, identify the main drivers of change, and diagnose where and why comfort improves or deteriorates. The assessment must incorporate meteorological local parameters.

**5.** Definition of the candidate mitigating measures on the basis of the diagnostics, through an interdisciplinary evaluation that weighs heritage compatibility, feasibility, and potential microclimatic leverage.

**6.** Integration of the selected mitigating strategies into the digital models to generate design scenarios. Through a new microclimatic assessment it is possible to quantify effectiveness relative to the baseline using consistent indicators.

If results are not satisfactory, iterate steps 5 and 6 by refining or recombining measures. When a configuration meets performance and compatibility targets, it can advance from feasibility to detailed design. The steps can be grouped into two main phases: the analytical phase, comprising steps 1, 2, 3, and 4, and the design phase, comprising steps 5 and 6.
The outcomes of the process are:

- Resulting from the analytical phase: the impact of climate change, urban morphology, materials, and vegetations on the microclimate;
- Resulting from the design phase: the effectiveness of the selected mitigation measures;
- Resulting from the entire process: the development of climate-sensitive operational indications for local administrations, easy to understand and to embed into municipal urban planning as a guide for decision-making and interventions.





## 4.4 The Interdisciplinary Analytical Phase

The analytical phase is organised into two components, each belonging to a different discipline: the first addresses the heritage context analysis and maps to phases 1–2 of the UMD methodology, while the second undertakes the microclimate modelling and assessment and maps to phases 3–4.

### 4.4.1 The Heritage Context Analysis and Monitoring: Methods, Software, and Tools

In line with established principles of architectural conservation, any consideration or action on the built fabric should be preceded by an integrated phase of knowledge building and documentation[121]. In the complex, stratified condition of a historic settlement, this phase is particularly critical since it assembles a comprehensive body of information for a deep, multidimensional understanding of context, while also revealing systemic, historical, and functional relations among the parts of the settlement. It further elicits and structures the system of intangible values associated with places, practices, and collective memory, relating these to the material fabric. In addition, it identifies strengths and weaknesses, vulnerabilities, criticalities, and opportunities across urban and architectural scales. Finally, it produces decision-grade data that can be re-used in subsequent phases of the methodology.
The data-collection strategy for buildings and the urban environment follows recognised guidance for heritage recording, particularly the notions contained in ICOMOS "Principles for the Recording of Monuments, Groups of Buildings and Sites"[122] and Historic England's "Understanding Historic Buildings. A Guide to Good Recording Practice"[123], which see recording as an essential stage of conservation that captures configuration, condition, and use at defined points in time, and that structures information for decision-making and re-use. The data gathering phase encompasses both research through secondary sources (bibliography, archival documents and maps, historic photos, existing urban plans, orthophotos, satellite pictures, etc.) and direct observations (site visits, surveys, and photographic campaigns).
In this phase, a Geographic Information System (GIS) offers a single environment for collating data, systematising it, georeferencing records, and organising them into thematic categories. GIS are now widely recognised as

121 The requirement to ground any analysis or design in thorough prior knowledge of context is set out in the conservation charters (Gazzola et al. 1964; Ministry of Education 1972). This principle also underpins major conservation theories, including those of Brandi and Riegl.

122 ICOMOS 1996.

123 Historic England 2016.

central to heritage recording and management. They provide the technological framework to meet the long-standing requirement to identify and document cultural heritage assets, assembling a coherent documentary apparatus, and making those assets manageable for future protection, planning, and monitoring actions.

Before fieldwork, a planning phase should be undertaken to define what information must be collected, how it will be gathered, and the systematic workflow to be followed. A preliminary delineation of the settlement is prepared within QGIS, an open-source, cost-effective, and flexible software implemented in the present research, If possible, it is reccomended using an existing base, preferably an existing, quality-checked survey or authoritative GIS layers. The area is then subdivided into elementary units; although this operation may appear straightforward, identifying the elementary unit of the urban aggregate means choosing the principles by which the built fabric is to be studied[124]. In this methodology, the elementary unit is the Building Unit (BU), defined as the subdivision of the settlement fabric into parts characterised by homogeneous typological features and functional autonomy. This notion is not tied to a universal, ownership-based parcel; rather, it is a cultural construct rooted in the specific context in which the unit emerged

124 Strappa 2021, pp. 8-9.

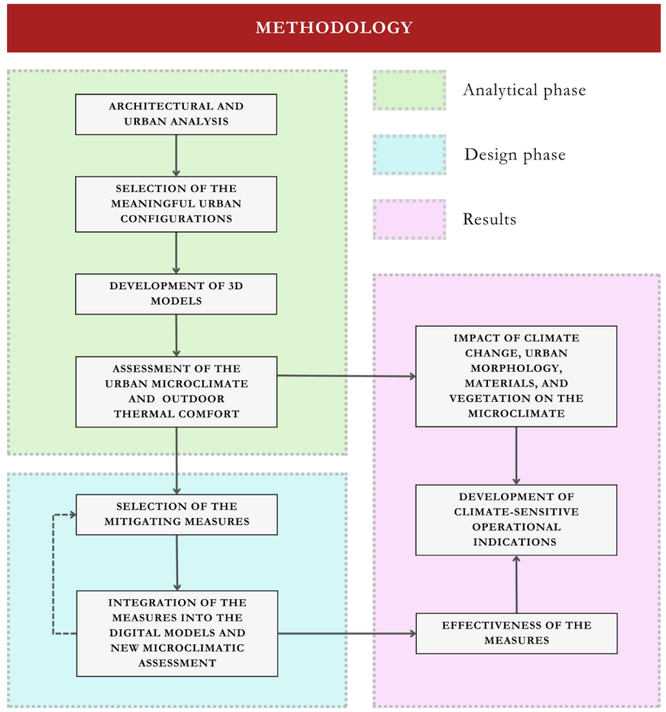



**Fig. 70**
*Diagram of the proposed UMD methodology for heritage and climate-oriented approaches. The graphic highlights the analytical phase and design phase, as well as the results of the process. Source: Author's graphic elaboration.*





and has transformed over time[125]. Where prior material exists, a desk-based verification of the BUs is undertaken; otherwise, a reasoned hypothesis is formulated and tested *in situ*. It is essential to assign each BU a unique identifier, so that every item of information can be referenced unambiguously and a systematic census can be conducted during fieldwork. Prior to survey, a record sheet is defined, specifying the attributes to be observed for BUs and for open spaces. In accordance with the ICOMOS guidance, the BU record captures at least the following:

- Chronological phase of construction;
- Volumetric and dimensional data;
- Materials and constituent parts;
- Typological characteristics;
- Technological aspects and traditional and modern construction techniques used for the various parts;
- Joinery and metalwork details, including windows, shutters, grilles, railings, and the presence of balconies;

125 *Ibidem.*

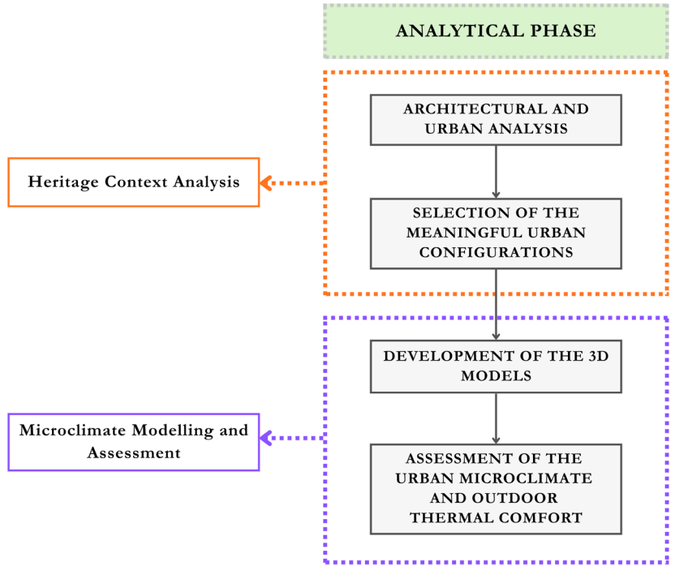



**Fig. 71**
*Diagram of the analytical phase divided into four steps, organised into two components. Source: author's graphic elaboration.*

- Finishes and decorative apparatus;
- Use characteristics, noting whether occupied or abandoned, typology of use, and any visible evidence of subsequent histories of use.

In addition, two evaluative ratings are recorded that will underpin the identification of vulnerabilities and strengths:

- Assessment of current state of conservation, evaluates the present physical condition of the building, including structural stability, integrity of materials and finishes, weathering and decay mechanisms, and the severity and extent of observable defects;
- Assessment of the degree of transformation of the original building fabric: measures the extent to which significant original elements and their relationships have been altered or replaced by later interventions.

As for the public spaces, the attributes recorded concerned:

- Pavement materials and build-up;
- Presence, type and height of vegetation;
- Presence and type of street furniture;
- Presence and type of lighting units.

In addition, two evaluative ratings were applied:

- Assessment of the current state of conservation of pavements and street furniture: evaluates physical condition and integrity;
- Assessment of the degree of transformation of historic pavements: measures the extent to which historic surfacing have been altered or replaced by later interventions.

During fieldwork, the record sheet is completed on site, element by element, in parallel with a photographic campaign for reference. Afterwards, the gathered data is confronted, verified, and enriched through the information avaiable in secondary sources. The records are then normalised and linked to the corresponding BU within the GIS. To handle heterogeneous observations, descriptions can be normalised into semantic categories calibrated to local variability, while evaluative ratings are defined with explicit indicators parameters. The resulting dataset is visualised as thematic maps, generated via spatial queries in QGIS, providing a systemic representation of patterns and relationships (e.g. degree of preservation of traditional construction techniques, identification of historic built clusters, etc.). This supports not only the recognition of phenomena but also the interpretation of heritage values and the identification of risks affecting the study area.
When BUs footprints are attributed with reliable height information and referenced to an appropriate terrain model, QGIS can assign vertical coordinates and generate a three-dimensional model of the settlement that



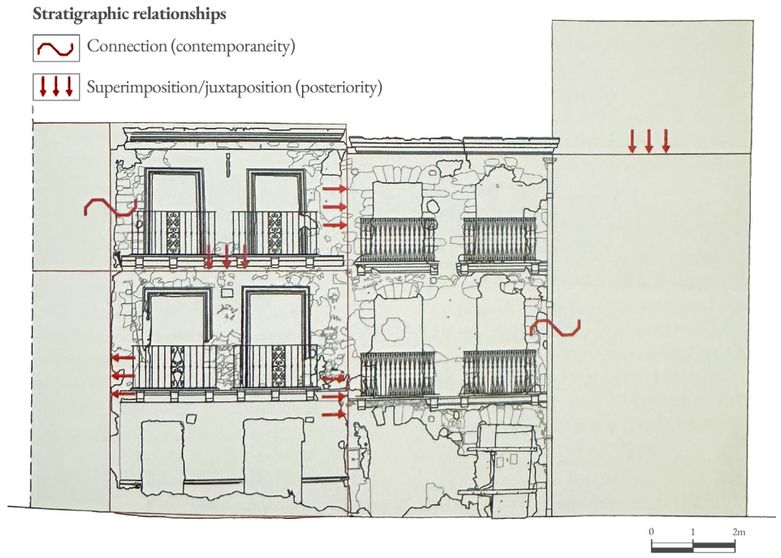


approximates its spatial configuration with documented accuracy. This 3D representation can efficiently support the development of the stratigraphic urban analysis aimed at reading the settlement diachronically and tracing the settlement's evolution over time. Reconstructing the phases of expansion of a historic village and assigning them precise dates is a complex task. For example, in Sardinia, the economic and civic organisation of rural life around the village remained stable for centuries and, as a result, the origins of most Sardinian historic villages can be traced back to medieval times. At the same time, one must also consider the repeated reconstructions undertaken for structural reasons, for the advancement of building techniques, or for changing needs, together with the substantial alterations introduced in the nineteenth century with the development of infrastructures and the importation of modern building techniques and materials.
Urban stratigraphic analysis can serve as a valuable tool in this regard, as it allows for the interpretation of the evolutionary genesis of buildings through the observation of their constructional features and the coding of their transformation processes. It consists of applying the stratigraphic method, originally developed in archaeology, to the historic urban fabric. The approach has been widely explored in methods and operational protocols, especially with regard to its application to urban elevations[126]. Within the present research, the method is particularly useful because modifications to the urban fabric may have significantly influenced the urban microclimate, through changes such as increases or decreases in building volumes, alterations of block configurations, street section modifications, or variations in building materials. Over time, these evolutions of the urban fabric may have altered the interactions between the built environment and climatic–environmental factors.
Applying the archaeological method to the urban context makes it possible to identify relationships of succession or contemporaneity among urban stratigraphic units, leading to the definition of a relative chronology, and subsequently, where datable elements exist, to an absolute chronology. While it is widely applied at the architectural scale, the use of this approach at the urban scale remains limited. A study carried out in 2009 on the residential fabric of the Stampace Alta district in Cagliari, however, highlighted the potential of the analysis at the urban scale, using the individual façade as the reference unit[127] (Figs. 72, 73). This was chosen within a hierarchy of seven reference units, from the most general one to the most particular, including the architectural complex, the building body, the general façade, the individual façade, the functional unit, the horizontal surface, and the architectural element[128]. In this case, the stratigraphic unit of the detailed elevation was defined as "*that portion of elevation recognisable as unitary from a constructional, material, and formal point of view, able to characterise a specific moment in the history of the building,*

126 e.g. Harris 1979; Mannoni 1984; Doglioni 1997.
127 Fiorino 2010.
128 Brogiolo 1988, pp. 15-17; Fiorino 2009, p. 79.

**Fig. 72 (above)**
*Stratigraphic relationships between facades in Stampace, Cagliari (Italy). Contemporaneity and posteriority relationships. Source: Fiorino 2010, p. 71.*

**Fig. 73 (below)**
*Part of the stratigraphic analysis in a street profile in Stampace, Cagliari (Italy). Source: Fiorino 2010, p. 72.*










*a 'relative time' T(x) to which previous or subsequent transformations can be referred*'[129].
Nevertheless, in the case of historic villages, the consideration of the façade alone may not be sufficient. Traditional mechanisms of cell multiplication along the street front or the superposition of several storeys are often accompanied by building expansions or the addition of new wings at the rear of plots, filling urban voids and internal courtyards. In such contexts, a three-dimensional approach to urban stratigraphy is preferable, as it allows the built environment to be analysed in its entirety. Thus, here the approach was innovatively applied to the chosen urban context by considering each stratigraphic unit as a three-dimensional portion of building, defined by coherent construction techniques, materials, and formal features that correspond to a specific historical phase of the structure.
Various stratigraphic relationships may exist among the units, reflecting all possible forms of transformation of the built heritage over time: connection (contemporaneity), superimposition/juxtaposition (posteriority), interruption/demolition, filling, and covering. The classical procedure adopted in stratigraphic analysis follows these steps: identification and description of the stratigraphic units; definition of the relative chronology among the analysed units; identification of absolute dating elements; and assessment of the absolute dating of undated elements through their stratigraphic relationships with datable ones[130]. When applied to historic villages, the identification of three-dimensional urban stratigraphic units requires the support of different tools, in order to simultaneously control visible elevations and roofs, the plan configuration, and the three-dimensional form of the building. These can include photographic documentation, cadastral maps, and satellite photos or ortophotos. With regard to defining relative chronologies, criteria may include the use of materials, construction technologies, and techniques, as well as the identification of discontinuities in masonry or differences in conservation state and progression of decay phenomena. Absolute dating elements are not always available, particularly in the case of small historic villages for which written records and extensive documentation are often lacking. In such cases, historic cadastral maps may prove useful, as they can at least indicate whether certain buildings already existed at the time of the map or were built afterwards, or they may help establish a probable time range for construction. Additional reasoning may also be based on the appearance of specific materials or construction techniques within certain geographical contexts.
It should finally be emphasised that the purpose of urban stratigraphic analysis is not to identify the most recent additions or alterations in order to dismiss them *a priori* as extraneous or invaluable. Rather, the goal is to develop a profound awareness of the pre-existing fabric, in which even the most recent additions may constitute an enrichment of the historic substratum. Defining the constructional types of an urban fabric while disregarding this phase

129 Fiorino 2010, p. 70.
130 *Ibidem.*

means working with typological "catalogues", based solely on presumed similarities that do not necessarily rely on historical foundations[131].
As discussed earlier, the urban-architectural and microclimatic perspectives are intertwined. When the evidence allows, urban stratigraphic analysis can reconstruct how the settlement looked at specific times, from which representative configurations can be selected for comparative microclimate modelling. For instance, if the goal of the study is to evaluate the influence of urban morphology on local microclimate, a past configuration can be reconstructed via stratigraphic analysis and compared with the current configuration in the following steps of the methodology.
Building on the heritage context analysis outputs, the study adopts the Italian "*Carta del Rischio*" as a GIS-based national reference framework for cultural heritage data gathering and monitoring[132]. Indeed, the incremental, updateable nature of GIS is particularly valuable since it enables the creation of an initial working baseline that can be refined and completed as new evidence is collected and re-used for subsequent updates. Established in the early 1990s and still active, *Carta del Rischio* combines census-level inventories with vulnerability and exposure assessments to support risk-informed conservation and decision-making. Therefore, *Carta del Rischio* is considered both a destination for harmonised data transfer from the local GIS and a benchmarking environment through which local findings can be situated within a wider territorial picture. The public-space layer is used as a pilot to demonstrate field-to-framework mappings and a monitoring-ready baseline.

131 *Ivi*, pp. 73-74.

132 Fiorani *et al.* 2022.

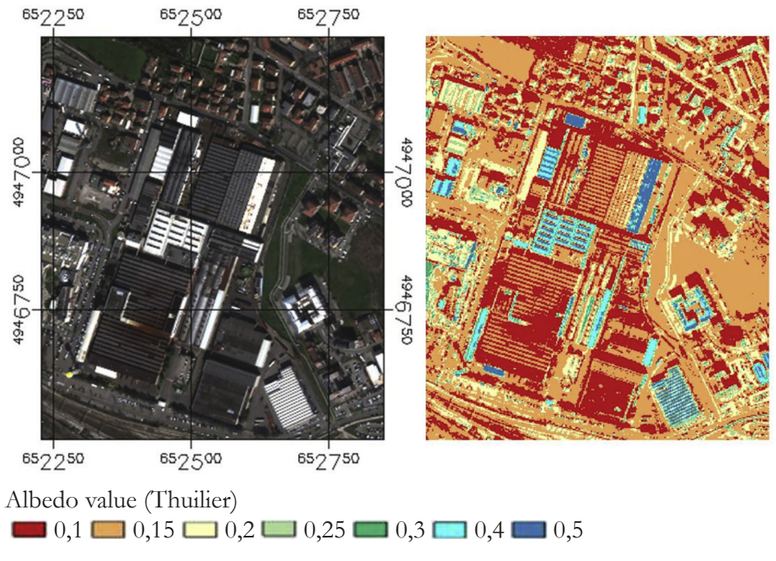



**Fig. 74**
*Detail of an industrial area in Modena, Italy, shown in an RGB satellite image (left) and an albedo map (right) derived from remote sensing data. Source: Despini et al., 2021, p. 5.*





### 4.4.2 The Microclimate Modelling and Assessment: Methods, Software, and Tools

In general, the assessment of the urban microclimate can rely on three categories of methods:

- Field-based measurements rely on meteorological instruments placed within the urban environment to directly record microclimatic variables. This approach can involve fixed weather stations, sensor networks or mobile measurement devices, each characterised by specific accuracy levels and measurement protocols. While such systems provide reliable, real-time observations, they typically offer limited spatial coverage and require careful calibration and positioning[133]. In compact historical settlements, local shading conditions, irregular street geometries and heterogeneous ground surfaces can significantly influence recorded values, making point-based measurements highly sensitive to siting effects. As a consequence, the generalisation of these data to the wider urban fabric must be approached with caution. Additional limitations concern the temporal and logistical constraints associated with extensive field campaigns, particularly when long-term monitoring or comparative scenario analysis is required. In historical villages, where access, infrastructure and power supply can be constrained, the deployment of dense sensor networks is often impractical. Moreover, field-based measurements describe existing conditions but do not allow the systematic exploration of alternative spatial or material configurations, which is essential when the objective is to evaluate potential climate-sensitive design strategies and scenarios;

- Remote techniques infer microclimate indicators such as temperature from a distance. They can rely on spaceborne sensors and satellite thermal imagery (e.g. Landsat, MODIS, ASTER) or on airborne sensors (e.g. thermal cameras, LiDAR, or multispectral cameras mounted on aircraft or drones)[134]. These methods provide high-resolution maps of surface properties and can achieve very broad spatial coverage at the scale of entire cities or regions, but they are both weather-dependent, since measurements can be affected by cloud cover and may capture only sunlit daytime conditions, and require expertise for data interpretation[135]. Satellite remote sensing also benefits from long-term archives for trend analysis and is extensively utilised for its accessibility and cost-effectiveness, while airborne remote sensing is comparatively expensive and subject to regulatory constraints, for example for drone flights[136]. While remote sensing techniques allow the extraction of surface-related parameters such as albedo or land surface temperature at an urban scale (Fig. 74), their

133 Chapman *et al.* 2016; Abdinoor *et al.* 2025.

134 Voogta, Oke 2002.

135 Imhoff *et al.* 2010; Rasul *et al.* 2017; de Almeida *et al.* 2021.

136 Klemas 2015.

application in historical villages is affected by significant limitations. The spatial resolution of satellite-based data is often insufficient to capture the fine-grained morphology of compact settlements. Moreover, remote sensing outputs mainly describe horizontal surface properties, while the microclimate of historical public spaces is governed by three-dimensional interactions between built form, materials, vegetation and human presence;

• Numerical modelling and simulation estimate microclimate variables using physics-based or empirical formulations, providing spatially continuous outputs, explicit control of boundary conditions, and access to variables that are difficult to observe directly. They can deliver detailed outputs as spatial maps and, when appropriately configured, capture airflow and heat exchange across scales from whole-settlement to street or building level. Computational fluid dynamics (CFD) models resolve fluid motion and its heat exchange with surfaces, and some tools tailored to the urban microscale also compute outdoor thermal comfort indices. These models are increasingly used because they are able to represent the complexity of the problem under study and because they allow scenario testing of real or hypothetical urban configurations, supporting comparative analyses between alternatives. They can also help isolate the effects of design changes such as trees, materials, or geometry, thereby informing planning and design decisions. However, they have a high computational cost and long runtimes, and they require detailed inputs and specialist expertise for geometry, material properties, and boundary conditions[137].

As previously indicated and for the mentioned reasons, the present study relies on numerical modelling and simulation, with a focus on CFD, to assess outdoor microclimatic conditions. This method produces spatially continuous depictions of urban space and can provide an urban-scale, fine-grained, and comparatively cost-effective assessment, as well as support comparisons between scenarios. This study employs ENVI-met[138], one of the most frequently used three-dimensional urban microclimate software for simulating the urban outdoor microclimate in complex urban and natural domains[139]. It represents the main variables involved, including the daily variation of solar position according to the chosen geographical location, and couples them within a gridded representation of the city. Using locally specified boundary conditions, ENVI-met produces spatial maps of the main drivers influencing the microclimate (e.g. direct and reflected solar

**Fig. 75 (next page)**
*Outputs of a numerical simulation run with ENVI-met, representing a residential district in Luoyang (China). The spatial maps represent the main drivers influencing the microclimate and the chosen outdoor thermal comfort index (PMV). Source: Wang et al. 2019, p. 1207.*

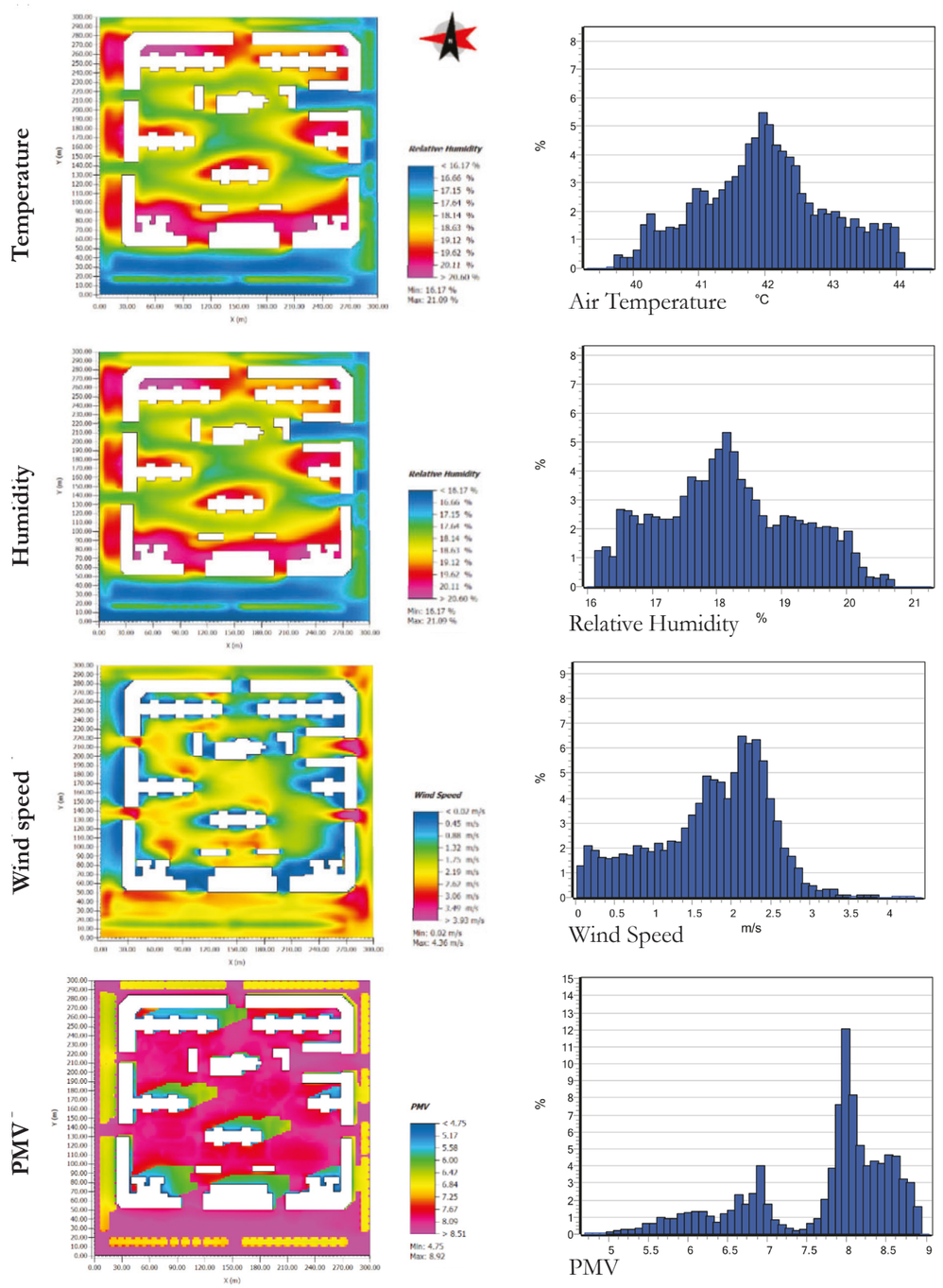
137 Blocken 2015; Toparlar *et al.* 2017

138 Presented by Bruse, Fleer 1998.

139 Following Fabbri, Costanzo 2020, p. 2, in 2020 ENVI-met was "*the most used tool for outdoor microclimate studies*". Some examples of studies employing ENVI-met are Dinić Branković *et al.* 2025; Fu *et al.* 2025; Zheng *et al.* 2025. The software has been also selected for microclimatic assessments by the Italian Agency for new technologies, energy and sustainable development ENEA, particularly in ENEA - Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile 2024.







radiation, wind speed and direction, relative humidity, air temperature, etc.), and derived outdoor thermal comfort indices. As illustrated in Fig. 75, ENVI-met simulations, unlike surface-based approaches, integrates the effects of urban geometry, material properties, vegetation and atmospheric conditions, allowing a spatial interpretation of comfort levels within public spaces. This capability is particularly relevant for historical villages, where outdoor comfort directly influences the usability, perception and social vitality of streets and squares.
To produce a reliable ENVI-met model of the studied context the following characteristics are needed:

- Site geometry and land cover: topography and terrain elevation (DEM/DTM); building morphology (footprints, heights), precise positioning of buildings, ground surfaces, water bodies, and vegetation; street furniture/obstacles if relevant (walls, canopies, fences); materials and surface (roofs, façades, pavements, soils) properties such as albedo/solar reflectance, emissivity, thermal conductivity, heat capacity, density, surface roughness, thickness/stratigraphy;

- Vegetation parameters: species or plant type, height and crown geometry, seasonal state and other specific properties such as optical properties and conductance;

- Meteorological data coherent with the simulated period, such as wind speed and direction, air temperature and relative humidity, solar radiation (global/diffuse) and precipitation if relevant.

In ENVI-met, surface materials (including their layered assemblies/stratigraphy) and vegetation are managed through libraries that provide default entries and can be extended with user-defined items. In this study, the availability of a QGIS geodatabase containing the site's geometry, material specifications, and vegetation attributes substantially streamlines model setup. The QGIS plugin "Geodata to ENVI-met" enables the direct export of the QGIS scene and the automatic generation of the ENVI-met model. For the export to execute correctly, each QGIS feature must include, within its attribute table, the identifiers that correspond to the relevant entries in the ENVI-met libraries (e.g., materials, soils, plant species), ensuring an unambiguous mapping between GIS entities and model classes. If the preceding methodological steps identified multiple meaningful past and present configurations of the settlement, these can be implemented as separate ENVI-met models, each retaining its own geometric, material, and vegetative characteristics.
Moreover, accurate meteorological forcing is essential for physically consistent ENVI-met simulations. Selecting meteorological forcing for ENVI-met should start from a clearly defined target period (e.g., a typical summer day or a heat-wave episode) and use data that are representative of the site. In practice, input data can be obtained from the following sources:

- Local weather stations: in situ observations from nearby official or research





stations are typically the first choice if a station is available in the proximity of the studied site[140];

- Global reanalyses: physically consistent, gridded datasets that blend observations with a numerical weather model to provide complete, gap-free time series of meteorological variables. Reanalyses are especially useful when local observations are unavailable or incomplete; they may, however, require bias correction or simple adjustments to reflect local conditions[141];

- Mesoscale downscaling: a regional weather model run at finer grid spacing over the study area to produce site-representative hourly fields of wind, temperature, humidity, and radiation. It is especially valuable where nearby stations are not representative or for event-focused analyses, but it requires additional modelling effort and validation against observations[142];

- On-site measurement campaigns: short- to medium-term deployments of portable sensors within or adjacent to the study domain. These campaigns provide highly representative forcing for the simulation period, but they require careful calibration, metadata on instrument exposure, and consistent sampling protocols[143].

Prior to execution of the simulation, the model numerics[144] and configuration are specified. The computational domain is sized to encompass the study area and an adequate upwind/downwind buffer. The horizontal grid is set fine enough to resolve urban geometry (street and courtyard patterns), and the vertical grid is refined near the ground and roof layers, with gradual stretching aloft to control computational cost. The time step, i.e. how much simulated time the model advances per calculation, is then selected. Surface materials, soil moisture, and vegetation state are set consistently with the simulation date. Finally, a test simulation is performed to verify the plausibility of wind direction, the diurnal cycle of radiation, and temperature evolution before running the full scenario[145].
The simulation results are then post-processed using "Biomet"[146], a tool integrated within ENVI-met that calculates human thermal comfort indices based on the model's atmospheric outputs. Outdoor thermal comfort (OTC) is commonly assessed with indices derived from human heat-balance models and/or empirical regressions. As noted earlier, many different indices are available. However, summarising OTC in a single quantity is complicated, as both objective variables (such as wind speed, humidity, temperature, solar

140 e.g. Florilo *et al.* 2023.

141 e.g. Wang *et al.* 2025a.

142 e.g. McRae *et al.* 2020.

143 e.g. Alves *et al.* 2022.

144 "Numerics" denotes the model's numerical solution choices.

145 To learn more about how to correctly set the software for simulation see Tominaga *et al.* 2008, Blocken 2015 or visit ENVI-met, n.d.

146 Biomet uses the Verein Deutscher Ingenieure 2008 to calculate indices.

irradiation, etc.) and subjective ones (as age, gender, activities, heat sensitivity, clothing, etc.) contribute to its definition. Among the thermal indices, the Predicted Mean Vote (PMV), based on the energy balance of an individual, will be adopted in this study. It is expressed as a vote representing the mean satisfaction (and the related thermal stress) sensed by a group of people, with zero being the vote for optimal comfort condition, positive values indicating thermal discomfort related to heat stress and negative values linked to cold stress. The Predicted Mean Vote (PMV) is standardised by ISO 7730 and, unlike other indices, can be evaluated directly using the measured or simulated quantities[147]. At the same time, PMV offers practical advantages for design testing when key inputs are known or deliberately standardised: a transparent parameterisation of clothing insulation and metabolic rate, which makes assumptions explicit and reproducible; a direct, scalar output on the familiar thermal-sensation scale that is easy to compare across alternative scenarios; and broad methodological continuity with indoor comfort standards and their outdoor adaptations, facilitating interpretation by practitioners[148]. Used in this controlled, comparative way, PMV provides a stable benchmark for comparison between different scenarios of outdoor thermal experience.
The model's outputs, spatial maps of the principal microclimatic drivers and of OTC expressed via PMV, processed with "Leonardo", ENVI-met visualiser, provide a coherent basis for comparing simulated scenarios. Viewed side by side, these maps enable assessment of the role of boundary-climate forcing on local conditions and support attribution of microclimate impacts to specific variables such as urban morphology, surface materials, and vegetation configuration. In this way, cross-scenario comparisons make it possible to isolate each factor's contribution and to draw evidence-based conclusions about both climatic and urban configuration effects on the microclimate.

147 Park *et al.* 2024.

148 International Organization for Standardization (2005) defines the PMV framework as an analytical method for predicting whole-body thermal sensation and the associated percentage dissatisfied in moderate environments. The standard specifies explicit personal inputs together with the environmental variables. Because these inputs must be stated *a priori*, PMV provides a reproducible basis for scenario comparability: differences in PMV can be attributed only to changes in the environment rather than to personal factors.





## 4.5 The Design Phase: Strategies and Solutions for Outdoor Thermal Comfort Enhancement

In the UMD methodology, various design and planning strategies are employed to optimise thermal comfort, air quality, and energy efficiency at both building and urban scales, contributing to the creation of comfortable, efficient, sustainable, and resilient environments[149]. Within the design phase of the methodology, mitigation measures are selected, detailed, and encoded in the previously developed ENVI-met models, so that new simulations can be run and their performance assessed against baseline results. This procedure can be iterated refining inputs and scenarios, until the outcomes reach satisfactory performance or until no further meaningful improvement is achievable. This approach allows for a place-specific assessment that can support design through successive stages while providing a clear view of how each option reverberates across the urban system. The aim is to weigh pros and cons *ex ante* and to anticipate impacts without committing resources to full implementation before the consequences are understood. In some cases, however, the do-nothing option proves preferable when interventions offer negligible benefits or entail disproportionate costs or risks. The selection of measures and the evaluation of their effectiveness should be guided not only by microclimatic performance, but also by criteria relating to environmental, cultural, and landscape compatibility; economic viability; accessibility and usability of space; and overall sustainability. Within this phase, simulation-based testing plays a crucial role in translating design intentions into measurable microclimatic outcomes, allowing alternative strategies to be compared and refined before implementation.
Excluding strategies whose primary objective is to enhance pollutant dispersion or energy performance, as their mechanisms differ from those used for outdoor thermal comfort, UMD strategies for improving outdoor thermal comfort can, following the consolidated classification in the literature, be grouped into four main categories[150]:

- Geometrical strategies, which rely on the shape, layout, and orientation of buildings or shading structures;
- Greening strategies, which exploit the thermoregulatory and shading properties of vegetation;
- Evaporative cooling strategies, which use the cooling potential of water through evaporation;
- Surface strategies, which optimise the thermal and reflective properties of ground and building materials.

Geometrical strategies primarily act by modifying ventilation and the sky view

149 Chiri *et al.* 2020.

150 Lai *et al.* 2019.

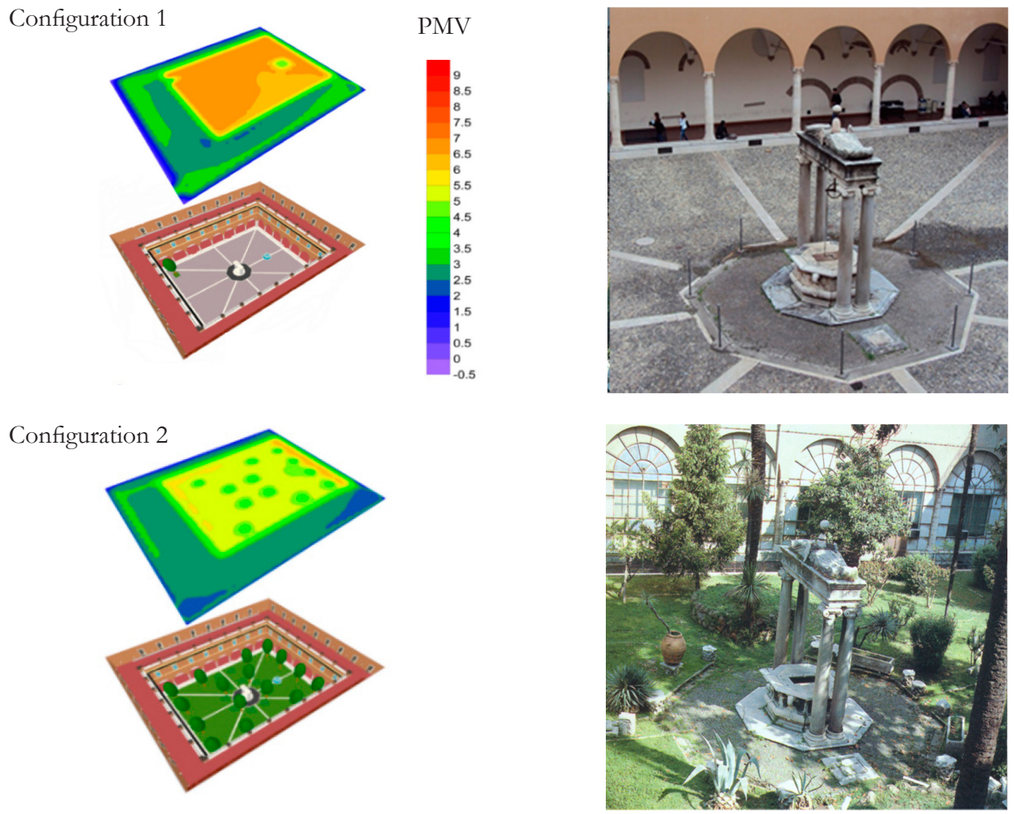



**Fig. 76**
*Comparison between two configurations of the cloister of San Pietro in Vincoli in Rome (Italy). On the right the two configurations, one with cobblestones paving in the present days and one with greening, dating back to the Nineties. On the left, PMV maps of the different configurations. Source: Salata et al. 2015, pp. 9017, 9022.*

factor (SVF). In the planning phase, strategies using the urban canyon aspect ratio[151], the building aspect ratio[152], the street orientation[153], the building shape (e.g. roof shape[154] or courtyard shape[155]), the building height change[156], the use of balconies[157], etc., can be effective. This category also comprises removable and reversible elements such as shading[158], windbreak structures[159], or wind-catchers[160]. Greening strategies act both passively, by modifying ventilation and shading, and actively, by reducing the surrounding air temperature through

151 e.g. Oke 1988.
152 e.g. Garau *et al.* 2019.
153 e.g. Ng 2010.
154 e.g. Ferrari *et al.* 2017.
155 Ferrari, Tendas 2024.
156 e.g. Nardecchia 2018.
157 e.g. Jon *et al.* 2023.
158 e.g. Cortiços *et al.* 2024.
159 e.g. Peng *et al.* 2022.
160 e.g. Zhang *et al.* 2024.





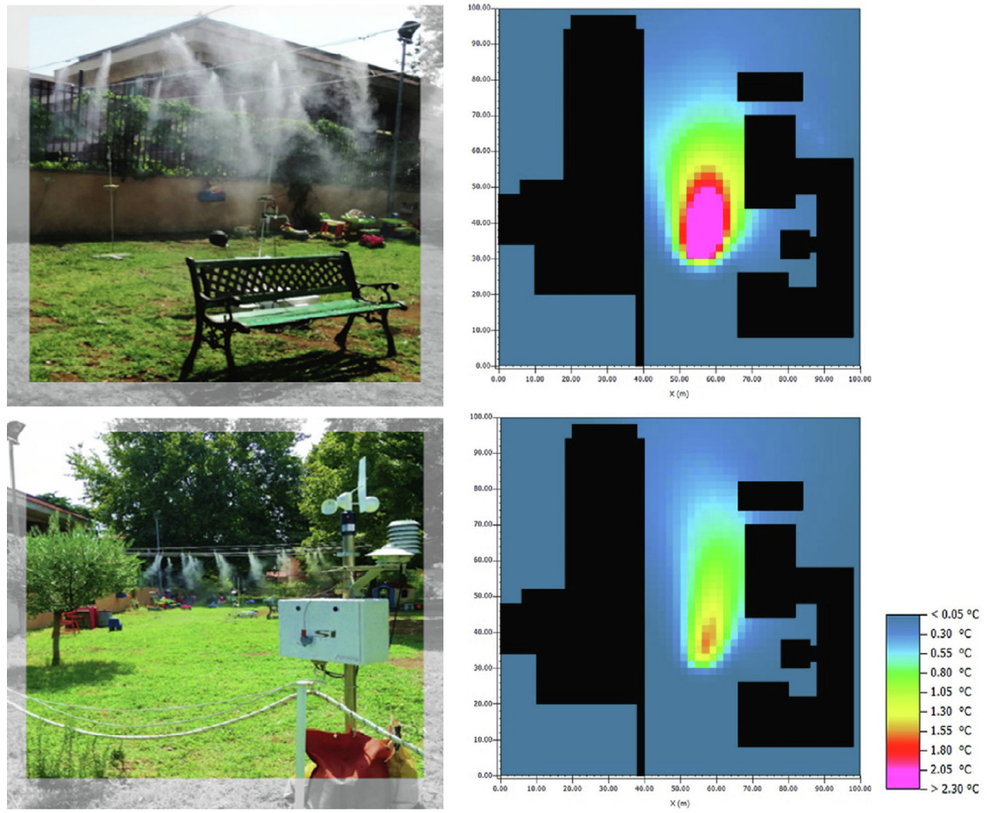



**Fig. 77**
*Assessment of the effectiveness of a misting system located in he urban district of Centocelle, Rome (Italy). On the left detail of the misting system and the meteorological station used for assessment. On the right, simulated temperature drop in the misted area at 2 p.m with different misting system settings. Source: Di Giuseppe et al. 2021, p. 4, 12.*

transpiration[161]. The comparative analysis reported in Fig. 76 exemplifies how ENVI-met simulations can be used to assess alternative design configurations ex ante. The comparison between the current cobblestone paving and a greener configuration of the cloister demonstrates how changes in surface treatment and vegetation can significantly affect perceived thermal comfort, as expressed through PMV distributions. Rather than providing absolute performance values, this type of analysis supports relative comparisons between design options, which is particularly relevant in heritage contexts where the range of admissible interventions is constrained. Green roofs or pavements[162], green walls[163], pergolas[164], and planting trees or edges, can be used both within planning phases and as an addition to existing settlements. Even if they have a measured positive effect on people's perceived comfort[165],

161 Oke 2002.
162 e.g. Cuce *et al.* 2025.
163 e.g. Zuckerman *et al.* 2025.
164 e.g., Watanabe *et al.* 2014.
165 e.g. Qin *et al.* 2013.

the increase of humidity and the maintenance costs must be taken into account.

Evaporative cooling strategies take advantage of the temperature drop due to the heat subtraction when water evaporates[166]. Typical interventions can be the introduction of artificial water bodies[167] or misting systems[168]. Fig. 77 further illustrates how simulation tools can support the calibration of evaporative cooling strategies. The results highlight that the cooling effect produced by misting systems is strongly dependent on operational parameters, spatial configuration and local climatic conditions. This confirms that such strategies cannot be assumed to be universally beneficial, but require careful testing to avoid undesired side effects, such as excessive humidity or limited effectiveness outside specific time windows. For example, these strategies can be effective in dry climates, where increased humidity can have positive effects.

Surface strategies typically make use of high-albedo materials (often referred to as cool materials) and surfaces to reflect the direct solar radiation and reduce the heat absorption[169]. Even if cool materials are effective on single buildings[170], many studies have highlighted that they cause a decrease in the outdoor comfort due to the reflected radiation[171].

Some studies have highlighted that the geometrical strategies are the most effective in reducing the outdoor human thermal stress, followed by the greening and evaporative cooling strategies, while some surface strategies tend to worsen the outdoor thermal condition, so they have to be studied carefully[172]. Indeed, as analysed before, high-albedo surfaces can increase pedestrian heat load by elevating mean radiant temperature. By contrast, combining measures (e.g., geometric shading with trees or evaporative elements) tends to outperform single interventions[173].

Comfortable urban outdoor spaces can highly improve the vitality of public spaces, bringing various benefits to the people in both physiological and social terms[174]. In historic urban contexts, mitigation strategies for microclimate should therefore be conceived both as instruments to improve outdoor thermal comfort and as tools to safeguard cultural significance, historic fabric, and landscape values. The objective is to create inclusive public spaces that remain meaningful to local identity while being accessible and usable for diverse groups. As shown by the examples reported in Fig. 76 and Fig.

166 Manteghi *et al.* 2015.
167 e.g. Xue *et al.* 2015.
168 Ulpiani 2019.
169 e.g. Kumar Domthu *et al.* 2024.
170 e.g. Santamouris 2014.
171 e.g. Yang *et al.* 2016; Taleghani, Berardi 2018.
172 e.g. Lai *et al.* 2019.
173 e.g. Zhao *et al.* 2024.
174 Wooley 2003; Yin *et al.* 2022.





77, the effectiveness of outdoor thermal comfort strategies depends not only on their typology, but on their spatial integration, configuration and interaction with local microclimatic conditions, reinforcing the need for simulation-based evaluation within the design process. Microclimate-aware design is often possible even in highly constrained heritage settings, provided that interventions respect the existing urban layout and fabric; nonetheless, this is challenging. Geometry-based measures, often the most influential, are typically subject to stringent planning and conservation controls. Local plans may prohibit changes to building envelopes, heights, or volumetrics; in other cases, specific landscape or heritage instruments may allow carefully framed transformations (e.g., demolition and reconstruction of volumes judged incompatible). Where such provisions exist, they can be leveraged to achieve solutions that both improve the landscape setting and deliver microclimatic benefits. More frequently, reversible or minimally invasive measures, such as deployable shading (canopies, awnings, tensile elements), greening strategies compatible with heritage (e.g., trees, climbers, pergolas), and evaporative measures at an appropriate scale, are preferable, subject to evidence of effectiveness in the local climate and to checks that they do not compromise other criteria (heritage significance, safety, accessibility, maintenance).

Several of these strategies draw on traditional solutions common in historic centres: deciduous vines or pergolas to provide summer shade while admitting winter sun; arcades, porticoes, and courtyard morphologies that modulate solar exposure and airflow; and context-appropriate materials whose optical and hygrothermal properties are already embedded in local building practice. An exemplary case is the village of Orani in Sardinia (Italy) with the "Pergola Village" concept, originally envisioned by Costantino Nivola (1953, Fig. 78) and recently reinterpreted by Stefano Boeri Architetti with the Nivola Foundation[175] (Fig. 79). It proposes a lightweight environmental framework that links dwellings with continuous vine-covered pergolas. The intent is to transform streets into intimate, collectively usable outdoor spaces, coherently with the Mediterranean tradition. From a bioclimatic standpoint, the scheme leverages seasonal shading and vegetation-driven evapotranspiration along circulation routes. Although quantitative performance data are not reported, the strategy is consistent with Mediterranean passive cooling logics that prioritise continuous shade, filtered light, and ventilated colonnade-like passages in heritage fabrics.

In other cases, traditionally used materials or solutions no longer deliver the same level of effectiveness as they did in the past due to changing conditions (first of all, climate change). Although the dedicated literature on mitigation in protected historic settings remains limited, the guiding principle is clear: preference should be given to proportionate, reversible, and evidence-led interventions that operate with the existing morphology before considering any more impactful modifications such as alterations of form. Moreover,

175 Stefano Boeri Architetti 2021.

**Fig. 78 (above)**
*Costantino Nivola, sketches for the "Pergola Village" in Orani, Sardinia (Italy), showing a continuous network of vine-covered pergolas linking dwellings (left) and a pergola-shaded street scene (right). Source: Nivola Museum collection.*

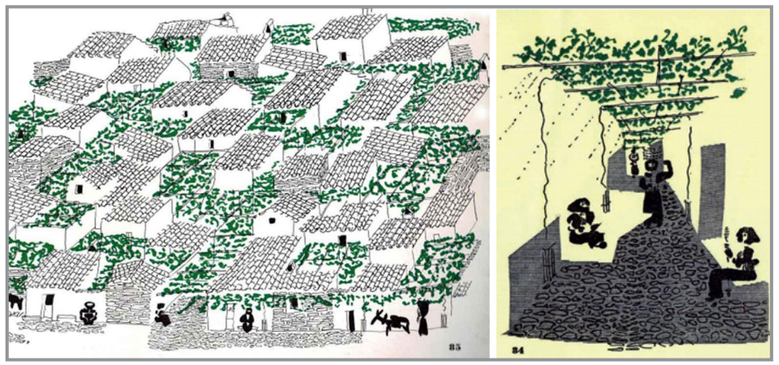


**Fig. 79 (below)**
*The "Pergola Village" project by Stefano Boeri Architects realised in Orani, Sardinia (Italy) in 2021. Source: Stefano Boeri Architetti 2021.*



given accelerating climate change and its associated uncertainty, strategies should also incorporate flexibility and reversibility so they can be adapted over time.
To reach such results, outdoor thermal comfort and microclimate considerations should be recognised as decision-relevant criteria in project briefs and planning instruments, not only to avoid counterproductive outcomes, but also to achieve the overall sustainability of the planned interventions and enhance prudent use of resources within the settlement. Public authorities need concise guidance on what to check in fragile historic contexts (e.g., vegetation compatibility, surface permeability, material choices), how to evaluate acceptability thresholds, and what alternative measures to prioritise if proposed solutions prove unsuitable. Even where enforcement is weak, clearly stated criteria and warnings help prevent interventions that would degrade both microclimate and heritage values.
While no single "recipe" can be prescribed for all historic settlements across the Mediterranean, context-informed observations can be distilled from the general characteristics of place and climate and translated into guidance. Such indications will be most reliable for contexts that resemble the study area and should be verified and adapted where local conditions diverge. The observations arise from: diagnostic analyses; comparative testing of alternative scenarios; assessment of the impacts of urban form, materials, and vegetation on the local microclimate; and evaluation of climate-change impacts for the site. On this basis, the indications for local administrations and professionals should set out: material attributes to scrutinise and their likely effects on outdoor comfort (e.g., albedo, emissivity, heat capacity, permeability); how to prioritise interventions accordingly to the dominant microclimatic drivers; mitigation strategies most suited to the context (e.g., geometry-based shading, heritage-compatible greening, calibrated evaporative elements, selective surface treatments); and the degree to which future warming and associated extremes should be factored into design targets.
This chapter has translated the theoretical, cultural and regulatory premises established in the preceding chapters into a structured methodological framework for the assessment and enhancement of outdoor thermal comfort in historic settlements. By integrating conservation principles with microclimatic analysis and simulation-based testing, the proposed protocol defines an operational pathway to support analytical interpretation and design decision-making within constrained heritage contexts.
While the framework is conceived to be transferable in its logic, its effectiveness can only be verified through application to a specific place. The following chapter therefore moves from the methodological construction presented here to its testing within a real settlement, using the historical village of Osidda to examine how the protocol operates when confronted with concrete spatial, climatic and socio-demographic conditions.

# Chapter 5.
# The Case Study of the Historic Village of Osidda

This chapter applies and tests the methodological framework developed in the previous sections through a concrete case study: the historic village of Osidda, in Sardinia. Osidda was selected as an exemplary small Mediterranean settlement that combines a compact historic fabric and clear signs of demographic and functional fragility. These conditions make it an appropriate laboratory for testing how microclimate-oriented conservation strategies can be translated into operational guidance at the urban scale.

Beyond its representativeness, Osidda offers a well-documented spatial and material structure and a scale that allows detailed microclimatic analysis while remaining relevant to the challenges faced by many small inland villages in the Mediterranean region. The case study is therefore used to explore the transferability and limits of the proposed methodology in real and constrained historic contexts. Accordingly, the chapter operationalises the protocol for microclimate assessment and mitigation, translating abstract criteria into site-specific analyses and testing how selected solutions can improve outdoor thermal comfort while preserving the cultural and morphological values of the settlement and supporting sustainable protection approaches in small municipalities.

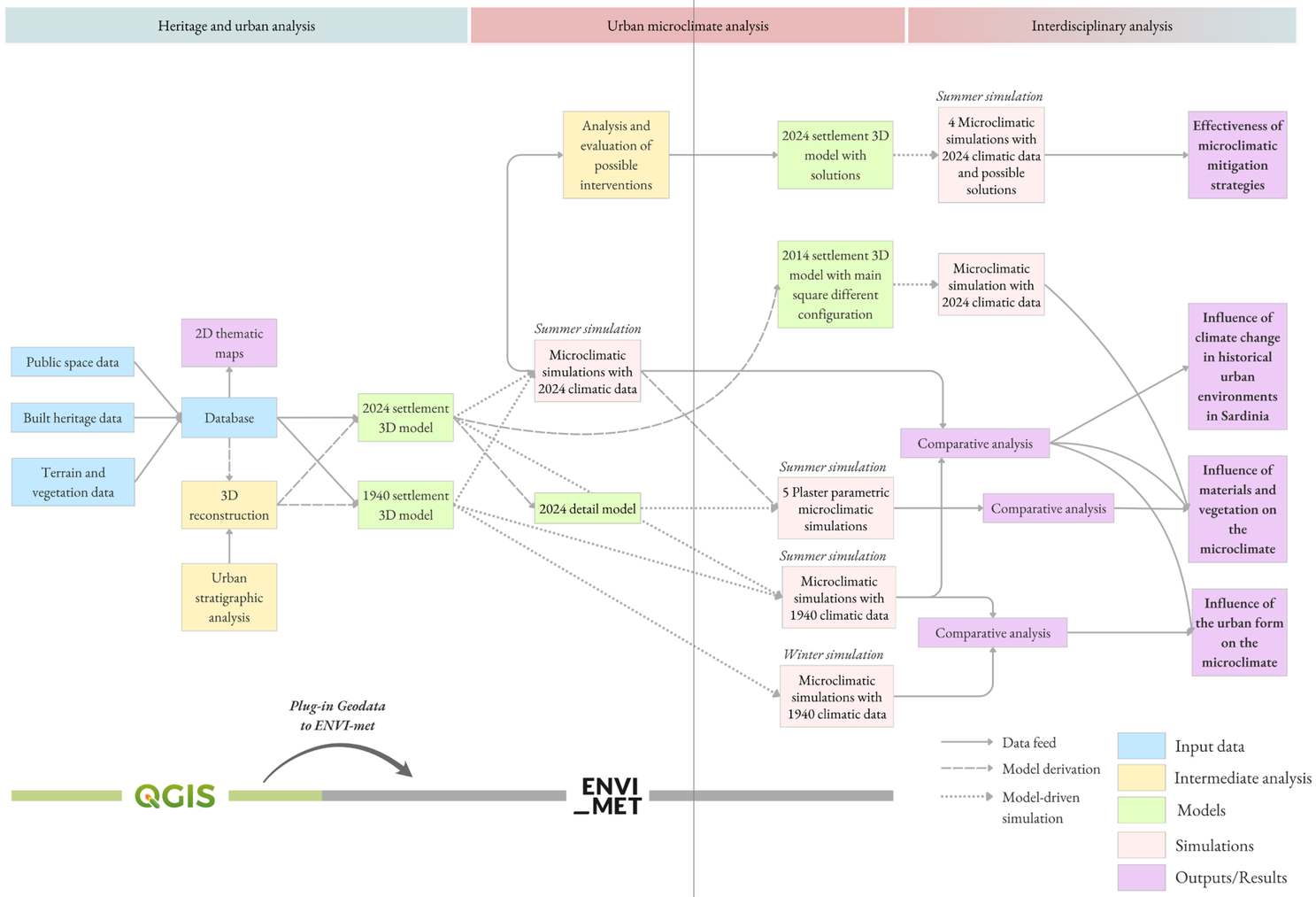



**Fig. 80**
*Flowchart of the exploratory pivot on the case study. It includes one database (2D, 3D), two 3D models, 14 microclimatic simulations and the use of two software. Source: author's graphic elaboration.*

## 5.1 Choice of the Case Study

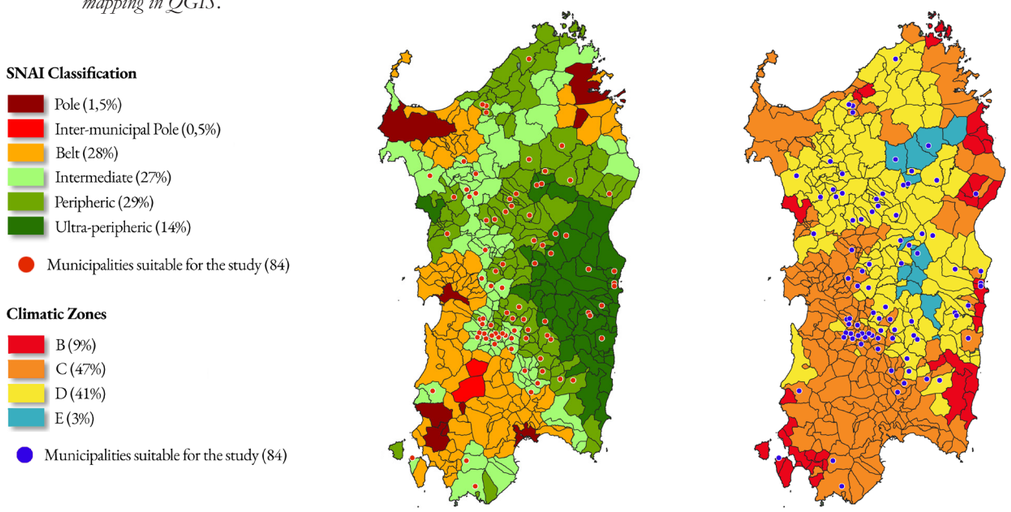
As discussed in Chapter 1, the term *borgo* (historical village) is characterised by a degree of definitional ambiguity within legislative and spatial planning frameworks. For the purposes of this research, explicit selection criteria were therefore established by drawing on the definitions provided in Italian regulatory instruments, including recent national policies such as the "Save the Villages" law and the lines of action of the PNRR Borghi programme.
On this basis, the case study was required to meet the following criteria:

- A cohesive urban structure and a traditional layout with recognisable historical, architectural and landscape values[1];
- A resident population of fewer than 5,000 inhabitants[2];
- A significant and ongoing depopulation trend[3].

Given that the overarching aim of the research is to explore strategies to improve quality of life in historic villages, the study focuses on settlements that remain inhabited, albeit by small communities. This condition is considered essential both for framing future revitalisation strategies and for enabling dialogue with local residents, including the possibility of participatory processes related to the future of the settlement.
Although the proposed methodology is transferable to other geographical and climatic contexts, the research focuses on Sardinia, with particular attention to its inner areas. This choice reflects three main considerations:

1 MiC 2021, line of action A, p. 4.
2 Italian Government 2017b, article 1, paragraph 2; MiC 2021, line of action B, p. 7.
3 MiC 2021, line of action A, p. 4.

**Fig. 81**
*Distribution of municipalities eligible as case studies in Sardinia. On the left, overlay with the Inner Areas categories defined by SNAI. On the right, overlay with climatic zones as defined in Italian legislation. Source: author's mapping in QGIS.*








- The limited attention devoted, including at the regulatory level as seen in Chapter 1, to the minor architectural heritage of inland villages compared to coastal settlements[4];
- The progressive isolation of these communities, which, despite depopulation and abandonment, have preserved significant cultural values;
- The widespread survival of traditional built fabrics that often retain original features, settlement patterns and bioclimatic functioning, seen in Chapter 2.

A preliminary list of Sardinian villages eligible for inclusion in the study was compiled according to the following requirements:

- Compliance with the selection criteria outlined above;
- The availability of a Detailed Plan of the Historic Centre consistent with the Regional Landscape Plan, providing a robust knowledge base for the analysis of urban fabric and identity features[5];
- Location within the national strategies explained in Chapter 1, namely Inner Areas recognised by the National Strategy for Inner Areas (SNAI), specifically the "Peripheral", "Ultra-Peripheral" and "Intermediate" zones.

These municipalities were subsequently classified through GIS-based analysis according to their climatic zone, in order to frame their environmental conditions within the regional context (Fig. 81).
Among the candidate sites, Osidda was selected as the case study. With

4 Reference is made to the Regional Landscape Plan, which, as of 2025, has not yet been updated to include the inner areas.
5 The list of the municipalities with compliant DPHC can be found in Autonomous Region of Sardinia 2012.




**Fig. 82**
*National and regional geographic context of Osidda, with a 2022 orthophoto of its built-up area. Source: author's graphic elaboration from Google Earth.*

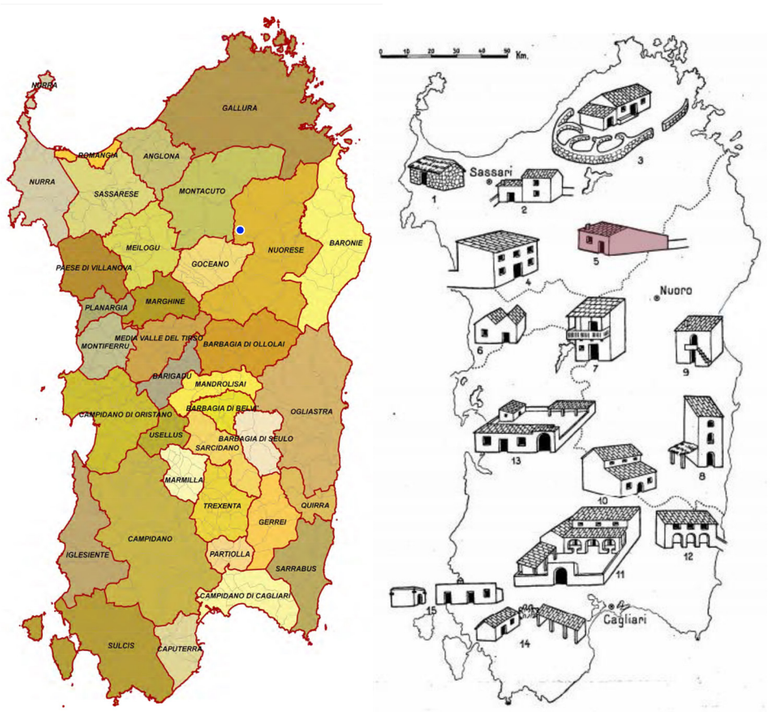



**Fig. 83 (left)**
*Localisation of Osidda in the context of the historical regions of Sardinia. Source: author's graphic elaboration from Autonomous Region of Sardinia 2013c, p. 8.*

**Fig. 84 (right)**
*On the right, identification of the most common rural house typology in Osidda among the rural dwellings cultures in Sardinia. Source: author's graphic elaboration from Baldacci 1952.*

217 inhabitants[6], it represents a compact hill village whose limited size and relatively simple urban structure, shown in Figure 82, make it suitable for detailed microclimatic analysis. Unlike many Sardinian settlements, Osidda largely retained its historic configuration during nineteenth-century infrastructural renewal, when street widening elsewhere often resulted in extensive demolition. Modest economic growth and recent depopulation have limited modern reconstruction, contributing to the preservation of the existing fabric; at the same time, LEADER I and II programmes[7] in the 1990s, already described in Chapters 1 and 2, supported the restoration and adaptive reuse of several historic buildings, helping to sustain local character. Osidda occupies a boundary position between the historic sub-regions of Nuorese, Logudoro-Monteacuto and Gallura (Fig. 83), a condition reflected in its settlement form and vernacular architecture, which combine characteristics of northern hill towns with typological models typical of the Nuorese area (Fig. 84). The village is therefore representative of a widely diffused stone-building culture in north-eastern Sardinia, particularly granite masonry.

6 ISTAT 2025.

7 European Union Common Agricultural Policy Network n.d. Osidda benefit from the Community Initiative LEADER, encompassing LEADER I (1991–1993) and LEADER II (1994–1999).





It falls within climatic zone D[8], one of the most prevalent on the island, and is expected to experience substantial temperature increases in the coming decades, as stated in Chapter 3, intensified by its inland location and limited maritime moderation[9].
The territory is affected by multiple vulnerabilities, including depopulation, decay of the built stock, municipal marginality (classified as "Peripheral" under the National Strategy for Inner Areas), and potential hydrogeological risk. Together, these conditions underline the relevance of Osidda as a testbed for investigating climate-sensitive conservation strategies. The case study further benefits from the availability of an adequate knowledge base, including municipal planning documents, local historical studies and cadastral archives, as well as from the presence of a small yet active community willing to share information and materials.

## 5.2 Historical, Landscape, and Urban Context

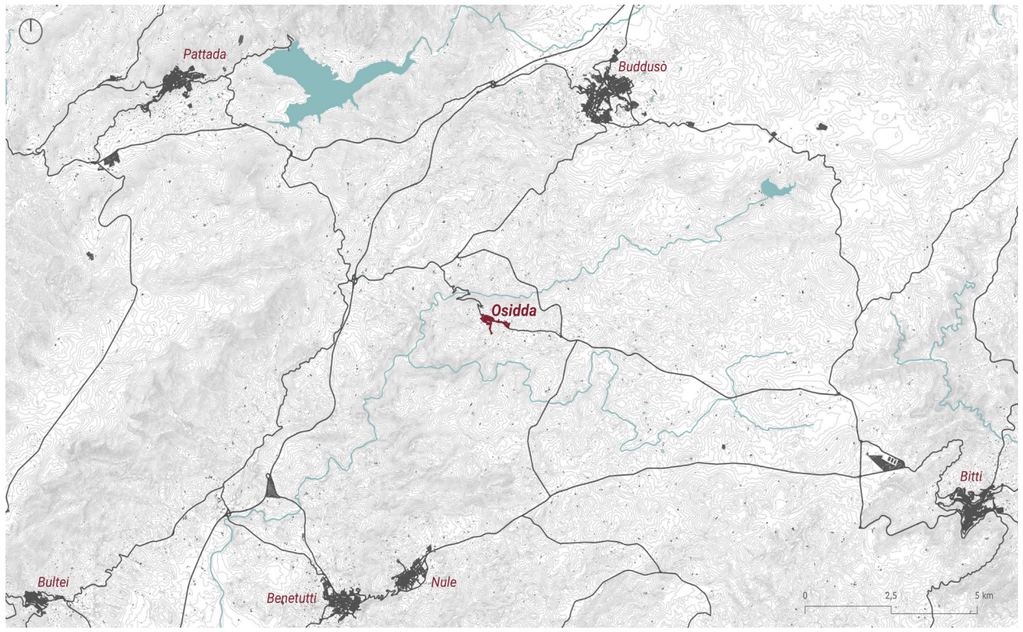
### 5.2.1 History, Environmental Characteristics, and Population

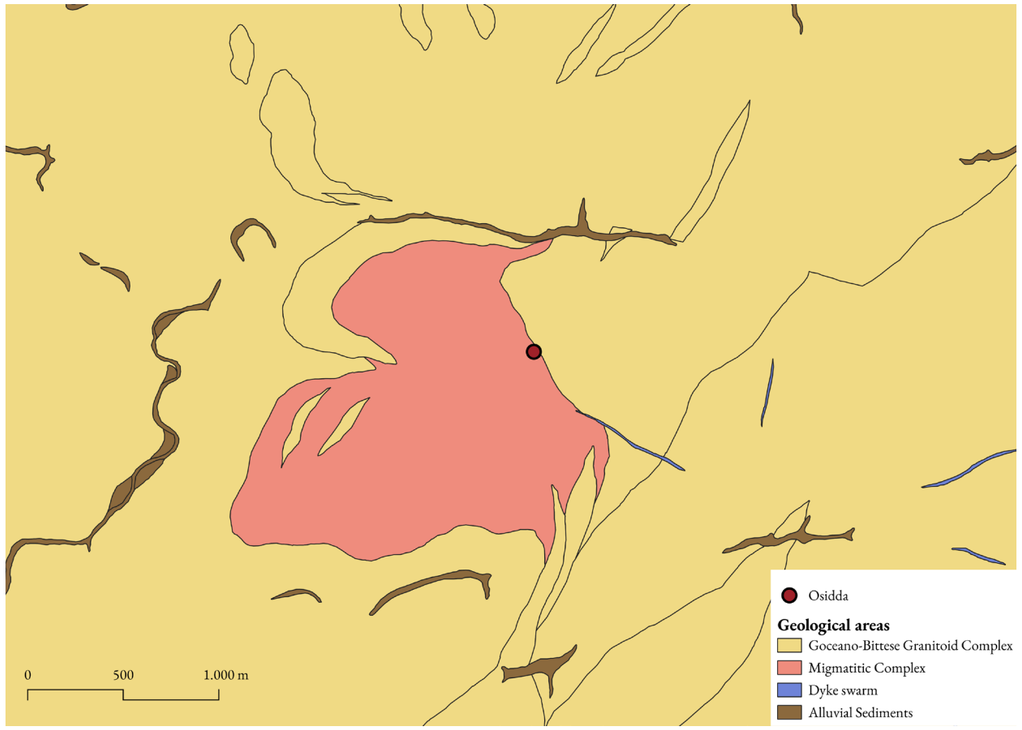
In the western sector of the Bitti–Buddusò granite plateau, within a largely level landscape characterised by oak woods and bounded to the north by the Tirso River and to the south by the Molò stream, lies the territory of Osidda. It borders to the east on the municipality of Bitti, to the south and south-west on Nule, to the north-west on Pattada, and to the north on Buddusò, in an area today called Nuorese (Fig. 85).
From a geological point of view, Osidda lies on the north-eastern Sardinian Variscan basement, at the margin between the Bitti–Buddusò granitoid plateau and a migmatitic domain. The area is dominated by the Goceano–Bittese Granitoid Complex, intruded into and locally contiguous with high-grade migmatites[10] (Fig. 86).
The area displays a Mediterranean climate with a marked upland signal: summers are short, warm and dry, whereas winters are relatively long, cool to cold, and breezy. Long-term summaries indicate average July daytime maxima of about 30 °C with nocturnal minima near 16 °C, while January averages are

8 Italian Government 1993b. In the Italian regulatory framework, national climatic zones are defined by degree days assigned to each municipality. The legal basis is Presidential Decree No. 412 of 26 August 1993, which classifies the national territory into six zones, from A to F as a function of degree days.

9 Maritime moderation arises from the high heat capacity and thermal inertia of seawater, which absorb surplus energy in summer and release it in winter, thereby damping both seasonal and diurnal temperature ranges. Sea–land breeze circulations also enhance daytime ventilation and inhibit the build-up of extreme heat inland; higher coastal humidity further reduces sensible heating. Locations far from the coast therefore exhibit a more continental regime with larger thermal excursions.

10 Barca, Cherchi 2002; Carmignani *et al.* 2016; De Luca *et al.* 2023.








close to 10 °C by day and around 1 °C at night. Rainfall follows the typical Mediterranean seasonality, with the wettest interval from late September to early May and a pronounced November peak, when the 31-day moving total is approximately 55 mm; July is the driest month at roughly 3 mm. Cloudiness is lowest from mid-June to mid-September, with July usually the clearest month, while winter is substantially more overcast. The windiest season extends from late October to early May, typically peaking in February, with prevailing flows from the western sector. Overall, these features delineate a strongly seasonal climate[11].

Sheltered by the natural topography (Figs. 87, 88) and endowed with numerous springs, the area has hosted successive civilisations since at least the Neolithic. The presence of *domus de janas*[12], remains of *tombe dei giganti*[13], and *nuraghi*[14] supports the hypothesis of a continuous life in the area. Among the most significant archaeological sites are the Nuraghe Usanis, a complex structure with two towers linked by a curtain wall; the Nuraghe Seris and Nuraghe Iscobalzu (Fig. 89), whose towers are still reasonably well preserved; and the Nuragic complex of Su Romanzesu, probably of a religious nature and now located within the territory of Bitti[15] (Figs. 90, 91). The abundance and quality of archaeological evidence suggest a strategic role for the Osidda plateau in antiquity, positioned along routes between the coastal harbour of Olbia and the Tirso valley leading towards central and southern Sardinia. This centrality was confirmed in the Roman period by the passage of the *via per mediterranea*, which linked Olbia to Cagliari[16]. The precise origins of the medieval settlement remain uncertain owing to the lack of detailed studies and archaeological excavations. Nevertheless, Osidda certainly existed in the Middle Ages, when it formed part of the *giudicato*[17] of Torres within the *curatoria*[18] of Monteacuto[19].

**Fig. 85 (previous page, above)**
*Localisation of the settlement of Osidda between Pattada, Buddusò, and Bitti. Source: author's graphic elaboration.*

**Fig. 86 (previous page, below)**
*Geological characterisation of Osiddian territory and surroundings. Source: author's graphic elaboration from Autonomous Region of Sardinia 2008c in QGIS.*

11 Weather Spark 2025. It's important to note that the data contained in the cited source are based on model reconstructions and can be imprecise.

12 *Domus de janas* are rock-cut hypogea used as collective chamber tombs in Sardinia during the Late Neolithic and Early Bronze Age, broadly from the fourth to the third millennium BCE, often modelled on domestic architecture and sometimes decorated with carved or painted motifs.

13 The *tombe dei giganti* are Nuragic megalithic collective graves, typically dating to the early second millennium BCE, with a long burial gallery and a semicircular exedra.

14 Casula 1994, p. 76. *Nuraghi* are drystone megalithic towers built by the Nuragic civilisation (c. seventeenth–ninth centuries BCE), typically composed of one or more tholos-roofed chambers; their function remains debated. The Nuragic period of Sardinian prehistory spans approximately from 1500 BCE until the Roman conquest in 238 BCE.

15 Taramelli 1931; Di Cecilia 1999, p. 17-20.

16 Zirottu 2005, p. 5-6.

17 The *giudicati* were the medieval polities of Sardinia, emerging from the late ninth century and lasting, in changing form, until the fifteenth.

18 The *curatorie* were territorial districts of a *giudicato*, administered by a *curatore*, and functioned as basic fiscal, judicial and military units aggregating villages and lands.

19 Zirottu 2005, p. 25.

**Fig. 87 (left)**
*The rural, hilly natural context surrounding Osidda. Source: author's photo, 2025.*

**Fig. 88 (right)**
*Osidda and its rural, hilly natural context. Source: author's photo, 2025.*





Nineteenth-century scholars of Sardinia, such as Alberto La Marmora and Canon Giovanni Spano, associated the origin of Osidda with that of the ancient Greek city of Ogrylle, the "twin" of Olbia (northern-east Sardinia). Beyond a small statuette depicting a bull with a human head[20], which can be related to Hellenic tradition, there are no documents or secure proofs to support this hypothesis. Some ruins discovered near the hill of San Paolo, to the west of the village, have nourished the idea that an earlier settlement developed there and was subsequently relocated to the site it occupies today, either because it was better protected by the surrounding heights or because access to water sources was easier. On the same hill are the traces of several ecclesiastical buildings, including the church of San Paolo, which cannot be securely dated although it is mentioned in a notarial document of 1597, and the church of San Pietro, which served as the parish until the eighteenth century[21].
Although Osidda appears in fiscal registers from the fourteenth century, where it emerges as a relatively prosperous and populated village, detailed descriptions of the settlement only become available from the early eighteenth century[22]. A report on feudal revenues drafted by Geronimo de Zabarayn describes Osidda as a small mountain village with around sixty houses and a

20 The figurine is known as the "*Toro androcefalo di Nulè*" or "*the Bronzetto di Nulè*", having been found between the territories of Osidda and Nule, and is now held at the National Archaeological Museum of Cagliari.

21 Zirottu 2005, pp. 6-13.

22 *Ivi*, p. 25.







**Fig. 89 (above)**
*Nuraghe Iscobalzu, Osidda. Source: photo by Valentina Pintus, 2021.*

**Fig. 90 (middle)**
*Archeological site Su Romanzesu, Bitti. Source: author's photo, 2025.*

**Fig. 91 (below)**
*Archeological site Su Romanzesu, Bitti. Source: author's photo, 2025.*





predominantly agrarian economy, characterised by a rugged terrain[23].
While Sardinia experienced a severe demographic and settlement crisis during the fifteenth century, its effects were uneven. More isolated inland and mountainous areas, such as the Nuoro district, appear to have been comparatively resilient, suggesting a long-term stability of interior communities and a persistent attachment to inland landscapes[24].
Following the annexation of Sardinia by the Savoy state, inspections carried out in the mid-eighteenth century provide further information on Osidda. An official survey of 1745–1746 reports a population of 225 inhabitants and describes a mountainous territory rich in pasture and cereal production, with good air[25]. A later survey from 1769 presents a more critical assessment, referring to a small and impoverished settlement of fewer than 300 inhabitants and noting concerns regarding water quality and local health conditions, while confirming its relative isolation within the surrounding territory[26].
More systematic demographic and environmental observations are provided by Vittorio Angius in the mid-nineteenth century. Between 1835 and 1850, Osidda is recorded as having 428 inhabitants distributed across 106 families, together with a diversified subsistence economy and the presence of archaeological remains in its territory. Angius also offers detailed remarks on local climatic conditions, describing cold and snowy winters, hot summers with occasional storms, and frequent fog in the intermediate seasons. These accounts highlight both the climatic severity of the inland setting and the long-

23 Bussa 1987, p. 426.
24 Scamardì 2020.
25 Viry 1957; Zirottu 2005, p. 34.
26 Bussa 1985, p. 233.




**Fig. 92**
*Historic centre delimitations (Original core from Municipality of Osidda 2015, plan 1 and Zone A from Municipality of Osidda 2002b, plan 1) and main contemporary expansion zones. Source: author's graphic elaboration from Google Earth.*





standing interaction between settlement form, environment and livelihoods[27].
On the basis of these reports and population censuses, we can observe that the number of inhabitants oscillated between roughly 200 and 400 from 1678 to 1838, partly due to periodic famines and epidemics, then increased to a peak in 1951, when 572 inhabitants were recorded. Thereafter a gradual demographic decline set in, driven by the crisis of traditional productive systems and the attraction of urban centres and coastal areas[28]. Today, depopulation continues to affect the village, and Osidda is the least populous municipality in the province of Nuoro[29].

### 5.2.2 The Urban Centre: Structure, Architecture, Constructive Culture

Today Osidda exhibits an elongated east–west urban configuration at roughly 650 metres above sea level. The settlement comprises a compact historic core built predominantly in grey granite, a material widely available owing to the granitic character of the area. Perimeter expansions of more recent date, and a newer residential cluster, extend eastwards along Corso Garibaldi (*S'Istradone* in Sardinian language), the present main thoroughfare, and to the south (Figs. 92, 93). Despite the inevitable accretions introduced from the 1960s onwards, the nucleus has substantially preserved both its original spatial organisation and the close relationship between buildings and public space (Figs. 94, 95). During the nineteenth century many historic centres with fine-grained,

27 Municipality of Osidda 2002a, p. 12.
28 *Ivi*, p. 16.
29 ISTAT 2025.




**Fig. 93**
*Main street names in Osidda. Source: author's graphic elaboration from Google Earth.*

minimal structures were cut through by the construction of new carriage roads. In Osidda the state road (Corso Garibaldi) was instead laid at the edge of the historic fabric, parallel to the two principal axes of the original core, Via Mazzini and Via Roma. Owing also to this choice, probably driven by technical considerations, the main characteristics of the traditional settlement have been retained to this day within an urban palimpsest where they coexist with more civic features that have formed along the new road infrastructure. The historic centre appears to have remained largely unchanged since about 1970, a condition likely linked to the steady depopulation trend. Characteristic of Nuorese hill towns, the layout is dense and compact, with dwellings set directly on to the street and only limited provision of courtyard space; as a result, public areas frequently operate as extensions of private domains, producing street scenes formed by continuous frontages of mostly low-rise houses. This arrangement was also a rational response to the stringent environmental conditions, which often required dwelling units to act as a mutually supportive system where each element occupied a precise position within the whole. The use of public space as an extension of the domestic sphere is also signalled by stone benches built along façades (Fig. 96), used both for mounting a horse and for seating, while the scarcity of private open areas for watering animals is reflected by iron hooks fixed to walls (Fig. 97), to which animals were tethered (*lorigasa*)[30].

The centre of Osidda is not particularly steep compared with other Sardinian settlements that climb the hillside, and changes in elevation generally occur longitudinally along the main axes. The building stock follows the gentle gradient of the terrain, with short flights of steps and raised thresholds negotiating minor level changes[31]. For example, in the Delogu Palace, the tallest noble residence in the village, the difference between Via Mazzini in front and the small square in Via Asproni is resolved by three granite steps (Fig. 98). Many units have been heightened over time and the resultant streetscapes are composed predominantly of two- and three-storey elevations. Lacking space to expand into courtyards, the elementary cell typically grew in two ways. First, vertical addition through an internal stair. Second, lateral extension along the street, producing a more extensive public elevation that could later be raised further. Remains of the hearth (*foghile*) are sometimes preserved in the kitchen (*coghina*, Figs. 99, 100), the domestic heart of the house, which supported multiple activities beyond cooking (Fig. 101). Even as storeys were added, the hearth kept its privileged position by progressively shifting upwards to allow the evacuation of smoke through the roof, while storage and service rooms occupied the lower floors and the remaining domestic spaces the intermediate levels. In the narrowest blocks the aggregation of contiguous cells often produced "through" houses that connected the uphill route with that downhill. Where the terrain allowed,

30 These informations have been gathered also thanks to interviews with the community.

31 Sanna, Cuboni 2009, pp. 45.53.









**Figs. 94 (above, left), 95 (above, right)**
*Glimpses of the village and its granite landscapes. Source: author's photo, 2025.*

**Fig. 96 (below, left)**
*Granite houses facades on Via Roma. Source: author's photo, 2022.*

**Fig. 97 (below, right)**
*Lorigasa fixed to the wall. Source: author's photo, 2025.*








**Fig. 98**
*Delogu Palace. The difference of ground level between the small square in Via Asproni (in the photo) and Via Mazzini (behind, where the main entrance is) is resolved by three granite steps. Source: author's photo, 2025.*











**Fig. 99 (left)**
*The reconstruction of a traditional kitchen in the last floor of Santina Paola Stevanin's B&B. The wooden floor is partially cover with stone to reduce the risk of a fire. Source: author's photo, 2025.*

**Fig. 100 (right, above)**
*An old oven preserved in a former house, which now forms part of the municipal library. Source: author's photo, 2025.*

**Fig. 101 (right, below)**
*An old foghile. Source: author's photo, 2025.*

the built fabric loosened the interdependence of cells to obtain small private yards according to existing needs[32]. In the oldest eastern sector of Osidda clusters of small cells reflecting an archaic organisation of extended family groups can still be recognised. Several dwellings converged to form a kind of enclosure whose shared open space operated as a collective court, sometimes "sacralised" by the presence of a well[33]. The wells survive only in communal memory today. Water supply systems have always been central in the village, supported by local springs and evolving during the twentieth century from a network of wells to a system of public fountains.

Within this matrix, similarly to other villages in Sardinia, the nineteenth century saw the emergence of the palazzo (*palattu*), an urban-derived house type introduced into a context otherwise dominated by traditional hill-town typologies (Fig. 102). This trend was reinforced by the rise of an agrarian

32 *Ivi*, pp. 54-69.

33 *Ivi*, p. 62.

bourgeoisie after the Enclosure Edict (*Editto delle Chiudende*)[34]. The appearance of new social actors prompted new building types, also promoted by the neoclassical school associated with the architect Gaetano Cima[35]. Conceived to display family standing in the public realm, these houses adopted rational and symmetrical façades that contrasted with the earlier rural vernacular and were regarded as more "decorous and civic"[36]. Such urban characters tended to homogenise the appearance of Sardinian towns, creating a kind of national style even before the Italian Unification. In the twentieth century a further distinctive feature spread across northern Sardinia, including Osidda, namely the *altana*, an elevated terrace formed by the vertical extension of the stair block (Fig. 103). This is one of the traits that Osidda shares with the hill towns of the north such as Ozieri, where *altane* are particularly numerous. Beyond its role as an architectural marker of prestige, the *altana* provided a practical vantage over family landholdings and served as a visual landmark associated with clan identity, emerging above the roofscape alongside other civic symbols such as the bell tower[37].

As noted in reports from the eighteenth and nineteenth centuries, the main activity in Osidda has always been pastoralism, followed by agriculture and craftsmanship. This is still legible in the landscape, where remains, although very rare, of the traditional shepherds' huts (*pinnettos* or *barraccos,* Fig. 104) can be found within a rural mosaic structured by the pasture enclosures (*tancas*). Building materials were sourced locally, as external trade was limited by long-standing environmental and cultural isolation, generally from scattered deposits rather than formal quarries (Fig. 105). Masonry techniques, discussed in detail later, rely on locally extracted granite and in some cases the presence of a bedrock bench at or near ground level meant that no artificial foundation was required, since loads could be transferred directly to rock (Fig. 106). Where this was not possible, a rubble foundation was laid and levelled to receive the walls. In rural stone construction the dwelling cell is enclosed by load-bearing walls, forming an efficient box both structurally and as a compositional module. One pair of parallel walls supports floors and roofs, while the other stabilises the whole to prevent overturning. Timber intermediate floors collaborate in this system, stiffening the structure and

34 Manconi 1984. The Enclosure Edict, issued in Sardinia in 1820 under King Victor Emmanuel I of Savoy, authorised the privatisation and fencing of common rural lands. This measure, inspired by liberal economic principles, disrupted traditional communal agriculture, favored the rise of a rural bourgeoisie, and deepened social inequalities between landowners and peasants.

35 Serra 1981. Gaetano Cima (Cagliari, 1805–1878) was the leading nineteenth-century Sardinian exponent of neoclassicism, trained in Turin and then in Rome under Luigi Canina and Luigi Poletti. Returning to Sardinia, he combined public practice with a long professorship at the University of Cagliari, and was pivotal in giving the island's towns a coherent neoclassical vocabulary that shaped civic and religious architecture across Sardinia.

36 Bianco, Cuboni 2009, p. 84.

37 *Ivi*, pp. 65-94











**Fig. 102 (above)**
*A palattu in Via Angioy.*
*Source: author's photo, 2022.*

**Fig. 103 (below, left)**
*Delogu Palace's altana.*
*Source: author's photo, 2025.*

**Fig. 104 (below, right)**
*The reconstruction of a pinnetto by Gavino Bazzu.*
*Source: author's photo, 2025.*

**Fig. 105**
*One of the local scattered deposit from where granite was quarried. Source: author's photo, 2025.*



distributing thrusts. To further reduce rotations and displacements, joists were often anchored through the wall to an external tie plate in metal or timber, and metal tie-rods were inserted within the masonry[38].
The cellular house exhibits a marked economy of openings for climatic reasons, limiting heat exchange with the exterior, and for structural reasons, preserving the capacity of the massive walls. In Osidda most windows are elementary, consisting of a small quadrangular opening spanned by a granite or timber lintel (Fig. 107), with plain reveals or reveals formed by squared monolithic stones. Other times the stone opening is finished with timber jamb linings that provide a fixing for the shutters and act as a weather check (Fig. 108). A fourth monolith is sometimes used as a sill (Fig. 109). A later development introduces slightly wider openings with a relieving triangle known as *cappuccina*, formed by two inclined monoliths set over the lintel (Fig. 110). Frames are often simple timber leaves, either plain or with *s'isperaglia*, a small vent in the main shutter (Fig. 111). In the nineteenth century timber windows with three glass panes per leaf became widespread, together with an internal shutter hinged to the main frame for darkening. Doorways may be rectangular (Fig. 112) or adopt a full-centred arch of nineteenth-century classicist derivation[39] (Fig. 113). In some cases the timber door is surmounted by a semi-circular or rectangular wrought-iron fanlight with decorative patterns that often incorporate the family initials. Balconies are a recurrent feature in the Nuorese area and have often been compared to the loggia in courtyard house types of the plains, as an external projection of the house and a means of shading the façade. In Osidda they are now relatively scarce,

38 Sanna, Cuboni 2009, pp. 163-169.
39 *Ivi*, pp. 185-187.







**Fig. 106 (above)**
*A wall built directly on the surfacing rocks.*
*Source: author's photo, 2022.*

**Fig. 107 (middle, left)**
*A window with a timber lintel.*
*Source: author's photo, 2025.*

**Fig. 108 (middle, right)**
*A window finished with timber jamb linings. Source: author's photo, 2025.*

**Fig. 109 (below, left)**
*A window with monolith lintel, reveals, and sill. Source: author's photo, 2025.*

**Fig. 110 (below, right)**
*A window with a cappuccina.*
*Source: author's photo, 2022.*









**Fig. 111**
*An old shutter with s'isperaglia in Gianfranco Doneddu's property.*
*Source: author's photo, 2025.*



mainly associated with the *palattus* of wealthier rural bourgeois families as part of a classicist vocabulary. Typically they consist of granite or wrought-iron brackets that support a thin stone slab and a wrought-iron railing, sometimes with decorations close to the Liberty style[40] (Figs. 114, 115).
The masonry box is generally covered by a mono- or dual-pitch roof (Fig. 116). Substantial timbers run either parallel or perpendicular to the pitch and may carry a secondary grid of smaller joists (Figs. 117, 118). An infill of reeds (Figs. 117, 118) supports the artisanal clay tiles known as *coppi sardi*, usually bedded on earth or lime mortar. Sometimes the reed layer is replaced by timber boards under tiles laid without mortar. Elsewhere the roof is supported by timber elements akin to a truss, depending on structural convenience. In the *palattus*, especially between ground and first floors, vaulted ceilings also occur[41]. The eaves–wall junction is among the most delicate nodes in stone construction since it must ensure the disposal of rainwater and prevent infiltration that can lead to deterioration and even disaggregation of the system. In a street frontage composed of a sequence of façades, eaves solutions become a defining character, a junction that is functional and expressive at once[42].
Intermediate floors are formed by single or double orders of timber beams with a timber decking (Fig. 119). Vertical circulation is provided by internal stairs, usually large granite steps (Figs. 120, 121). From the twentieth century onwards, and especially in its second half, Osidda progressively abandoned traditional construction techniques in favour of modern materials and

40 Sanna, Cuboni 2009, p. 188.
41 *Ivi*, pp. 198-203.
42 *Ivi*, p. 205.









**Fig. 112 (above, left)**
*A rectangular door with a timber lintel.*
*Source: author's photo, 2025.*

**Fig. 113 (above, right)**
*A door with a full-centred arch and a decorated wrought-iron fanlight.*
*Source: author's photo, 2025.*

**Figs. 114 (middle, left), 115 (middle, right)**
*Balconies with wrought-iron railing.*
*Source: author's photo, 2025.*

**Fig. 116 (below)**
*Houses covered by mono- and dual-pitch roof with coppi sardi. Source: author's photo, 2025.*

















**Figs. 117 (above, left), 118 (above, right)**
*Roofs with double-layer timber joist system and reeds.*
*Source: author's photo, 2025.*

**Fig. 119 (middle)**
*An intermediate floor with timber decking.*
*Source: author's photo, 2025.*

**Figs. 120 (below, left), 121 (below, right)**
*Granite stairs.*
*Source: author's photo, 2025.*





methods. Concrete block or reinforced-concrete walls (Fig. 122), concrete or brick lintels (Fig. 123), flat roofs (Fig. 124), concrete balconies (Fig. 125), and composite intermediate floors became widespread.

Public space comprises a network of routes that serve dwellings, act as collectively managed extensions of the neighbourhood and naturally collect and discharge stormwater. Where routes meet, small enlargements often occur (Figs. 126, 127). These do not function as true piazzas yet nevertheless operate as places of public encounter. In Osidda this was very common in the original layout. The main square today is Piazza Bonapace, created in front of the Town Hall (Fig. 128), which connects to Piazza dei Caduti along Corso Garibaldi (Fig. 129), along with other secondary squares and widenings. In recent years, Piazza Bonapace and Piazza dei Caduti underwent refurbishment, replacing the former stone setts (*sanpietrini*) and large planting beds with light-coloured granite slabs that create a flat, smooth surface. As part of the intervention, the square level was raised, partially covering the façades of adjacent building units, reducing greening space, and necessitating modifications to access arrangements; to resolve the resulting differences in level with the surrounding streets, new stairways were introduced. A particular case of public space is the so-called Piazzetta Delogu, a quadrangular space formed by extending Via Asproni as far as the cluster of Delogu family buildings (Fig. 130). It can be considered as a small private square, though unfenced, with a well at its centre that has since disappeared. Other larger gathering places are found near the church of Sant'Angelo (Fig. 131), south of the compact centre, adjacent to another collective space now arranged as the Andrea Parodi urban park (Fig. 132).

Another distinctive public space in Osidda is a covered passageway leading to a rear alley, accessed from the main square (Figs. 133, 134). Its form results



**Fig. 122**
*A recent construction with a concrete block structure.*
*Source: author's photo, 2025.*







**Fig. 123 (above)**
*Raising of a granite building with concrete blocks, composite intermediate floors, and brick lintel.*
*Source: author's photo, 2022.*

**Fig. 124 (below, left)**
*Raising of a granite building with tuff blocks, flat roof and brick chimney stack.*
*Source: author's photo, 2022.*

**Fig. 125 (below, right)**
*A concrete balcony in a granite building.*
*Source: author's photo, 2022.*











**Figs. 126 (above), 127 (middle)**
*Wideninga with granite benches where streets meet.*
*Source: author's photo, 2025.*

**Fig. 128 (below)**
*Piazza Bonapace, main square, often used as a parking.*
*Source: author's photo, 2025.*

**Fig. 129 (above)**
*Piazza dei Caduti along Corso Bonapace. Source: author's photo, 2025.*

**Fig. 130 (middle)**
*Piazzetta Delogu.*
*Source: author's photo, 2025.*

**Fig. 131 (below, left)**
*Sant'Angelo church.*
*Source: author's photo, 2025.*

**Fig. 132 (below, right)**
*The Andrea Parodi urban park. Source: author's photo, 2025.*

















**Fig. 133 (left)**
*The covered passageway and the suspended building.*
*Source: author's photo, 2025.*

**Fig. 134 (right)**
*The rear alley.*
*Source: author's photo, 2025.*

from a small suspended building that likely linked two dwellings belonging to the same family. The alley once ran longitudinally across the entire block but is now closed off by private gates.

Before the widespread adoption of modern paving systems such as setts, cement and asphalt, the urban fabric featured beaten-earth surfaces with stone details. Two side channels ran along house fronts to drain water and stone slabs bridged the threshold between street and dwelling (Fig. 135). Where resources permitted, pavements achieved a dignity beyond mere beaten-earth tracks. The construction method involved excavating to a stable layer, forming a settled foundation of stones and gravel, then laying the paving stones on a sand bed with joints filled by sand. In the historic core between Via Roma and Via Mazzini the roadway was paved in cobbles of rounded river stones of fairly regular size, which facilitated laying (Fig. 136). Cobble pavements are generally undecorated and respond simply to functional need. Later, larger stone pieces were introduced for delicate segments such as runnels and occasional stairways that negotiated level changes in public space (Fig. 137). Although partially compromised by modern replacements, several stretches remain well preserved (Fig. 138). They attest to a deep material culture and know-how that delivered durability with very limited resources. The same pavement sometimes appears in the few private courts that otherwise remained unpaved[43].

43 *Ivi*, pp. 238-242.



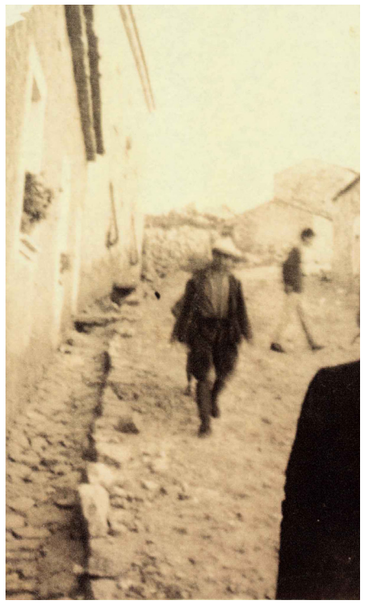




**Fig. 135 (above, left)**
*Historical photograph of the centre with cobble pavement, 1963. Source: Municipal library of Osidda.*

**Fig. 136 (above, right)**
*Historical photo in Via Sant'Angelo with beaten-earth tracks, side stone channels to drain water and stone slabs to enter the dwellings, 1940s. Source: Municipal library of Osidda.*



**Fig. 137 (middle)**
*Stone stairs to negotiate the change in level. Source: author's photo, 2022.*



**Fig. 138 (below)**
*Cobble pavement with contemporary cement addition. Source: author's photo, 2025.*





## 5.3 The Heritage Context Analysis: Knowledge and Interpretation

### 5.3.1 Development, Structure, and Thematic Layers of the Georeferenced Database

The architectural analysis of the historic village of Osidda[44] commenced with the subdivision of the settlement into Building Units (BUs). This preliminary articulation of the built fabric, based on the units previously identified in the Detailed Plan of the Historic Core[45], enabled the launch of a systematic photographic campaign and direct examination of the settlement's characteristics. In total, the entire settlement was divided into 493 BUs, grouped into 42 blocks. The BUs and blocks were subsequently mapped as georeferenced polygons in QGIS[46], improving upon a pre-existing base produced by the municipality, which was only partially up to date (Fig. 139). Each BU was assigned a unique identification code comprising a first component referring to the parent block and a second component indicating the BU's sequence within that block; for example, BU 08_12 denotes the twelfth unit within block 08.

44 This part of the experimentation was carried out with the Department of Civil and Environmental Engineering and Architecture, School of Conservation, University of Cagliari. Research group: Giulia Cherchi, Donatella Rita Fiorino.

45 Municipality of Osidda, 2015, plan 1.

46 QGIS version 3.34.10 - Prizren

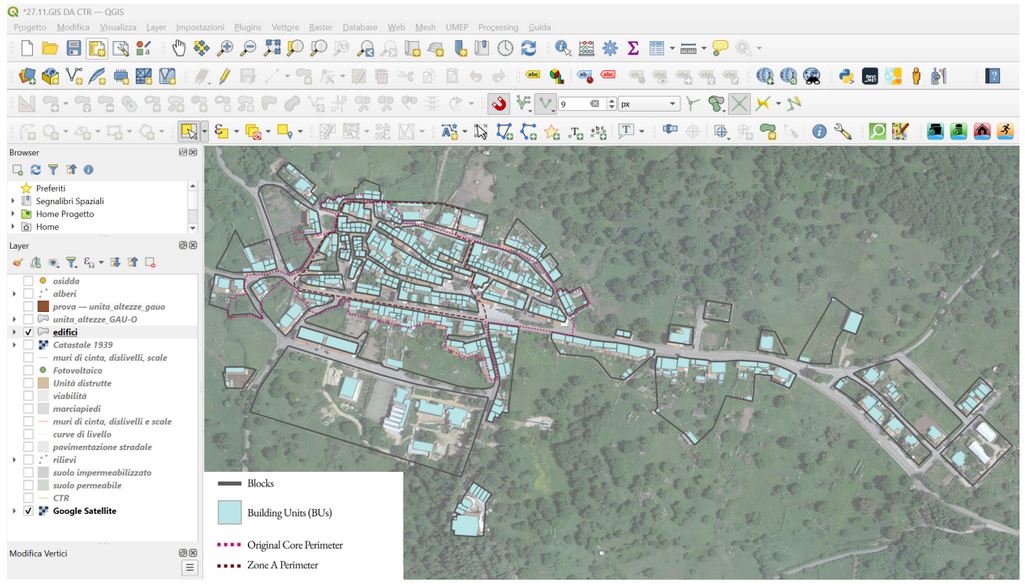



**Fig. 139**
*A preliminary articulation of the georeferenced database with the indication of the historic centre delimitations. Source: author's graphic elaboration from QGIS.*

The data gathering process focused on:

- The description of the historic urban space and architecture in terms of typology, volumetrics, construction techniques, materials, and use, along with observations on its current state of conservation and degree of transformation;
- The relationship between built and unbuilt spaces, considered in light of local geographic, topographic, climatic, social, and cultural conditions, as well as the functional, productive, and economic needs;
- The interaction between natural and manufactured elements within the inhabited space, with particular attention to vegetation;
- The evolution of the urban space over time in response to emerging needs.

These collected data were then enriched with information from indirect sources, including:

- Historical cadastral maps from 1848, 1939, 1960, and 2014, which, through overlapping, enabled the classification of BUs into chronological phases and served as the basis for the stratigraphical analysis;
- Urban planning documents, specifically the Detailed Plans for the Historic Centre[47]. The Detailed Plans include valuable information for the analysis of the historic urban fabric, such as the delimitation of the historic centre, identification, classification, and features of BUs;
- The Sardinia Region's geoportal[48], used to verify data through current and historical orthophotos and oblique aerial images, as well as to download the Digital Terrain Model (DTM);
- Google Earth and Google Maps to verify past configurations of the settlements, single BUs, vegetation pattern, and public spaces;
- Two monographs on Osidda, authored by local scholars, which focus on its history and territory[49];
- The Municipal Civil Protection Plan[50] and the Regional Environmental Forestry Plan[51], as the basis for the trees census within the settlement and its surrounding area;
- Historical photographs, offering visual documentation of the village between the 1930s and 1970s, which help reconstruct the past configuration of the urban fabric and its evolution[52];

47 Municipality of Osidda, 2002; Municipality of Osidda, 2015.
48 Autonomous Region of Sardinia n.d.
49 Di Cecilia 1999; Zirottu 2005.
50 Municipality of Osidda, 2012.
51 Autonomous Region of Sardinia 2007, Attachment n. 2.
52 The historical photographs were a courtesy of the Municipal Library of Osidda.





- The knowledge of local communities, fundamental in small villages in Sardinia, where data from indirect sources is often limited, was gathered through informal conversations with residents, which, although not structured interviews, provided essential insights into the historical use of spaces, daily habits, and local environmental perceptions.

The structured digital database allowed for the identification of numerous thematic layers in terms of built environment and public space: construction chronology, number of storeys and height, uses, building typology, masonry technique, roof type, eaves detail, window and door frames, ironworks, balconies, finishes, presence of distinctive architectural elements, retention of original fabric index, and overall conservation status (BUs); paving materials, urban furniture, the presence of retaining walls, footways, and ramps, retention of original pavement index, and overall conservation status (public space); altitude profile of the terrain, impervious and permeable surfaces, the species and height of vegetation, and the nature of soil (entire area of interest). The census was undertaken in the entire settlement only where features were observable from public accessible spaces or via digital sources such as web mapping portals and satellite imagery. Attributes that could not be observed owing to inaccessibility were recorded as "not ascertainable". The data entered in the attribute table of the various layers (BUs, public space, vegetation, and urban furniture) were used to produce thematic maps that provide a systemic representation of the phenomena, facilitating not only pattern recognition but also the interpretation of values and of the risks to which the studied heritage is exposed.

*BUs - Construction chronology, number of storeys and height*

The analysis of Building Units (BUs) was conducted considering the entire settlement, both traditional and contemporary constructions. With respect to construction chronologies was conducted by comparing the current condition with selected historical cadastral sources, in order to understand how the built fabric developed over time. The sources consulted were the "De Candia" cadastre of 1849, the historical cadastre of 1939, and that of 1960. On this basis, the historical evolution of the village was mapped through four plates corresponding to the following periods: pre-1849; 1849–1939; 1939–1960; post-1960 (Fig. 140). In addition, the number of storeys (Fig. 141) was recorded to derive an approximate total building height. This initial phase provided the basis for the subsequent stratigraphic analysis.

*BUs - Uses*

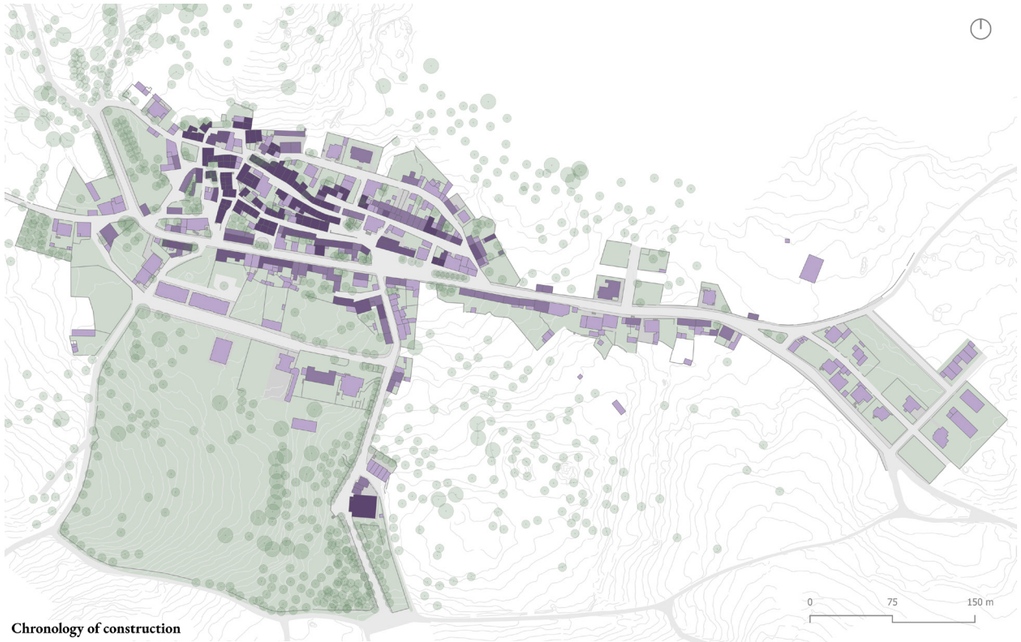
The analysis of each BU distinguishes between state of use (not in use, in use, partially in use; Fig. 142) and use designation (administrative, Fig. 144; commercial; cultural, Figs. 145, 146; infrastructure; institutional; industrial/productive; residential; ancillary to residential use, e.g. storage or garage; religious; recreational; health care; sports; tourism and accommodation; Fig. 143).

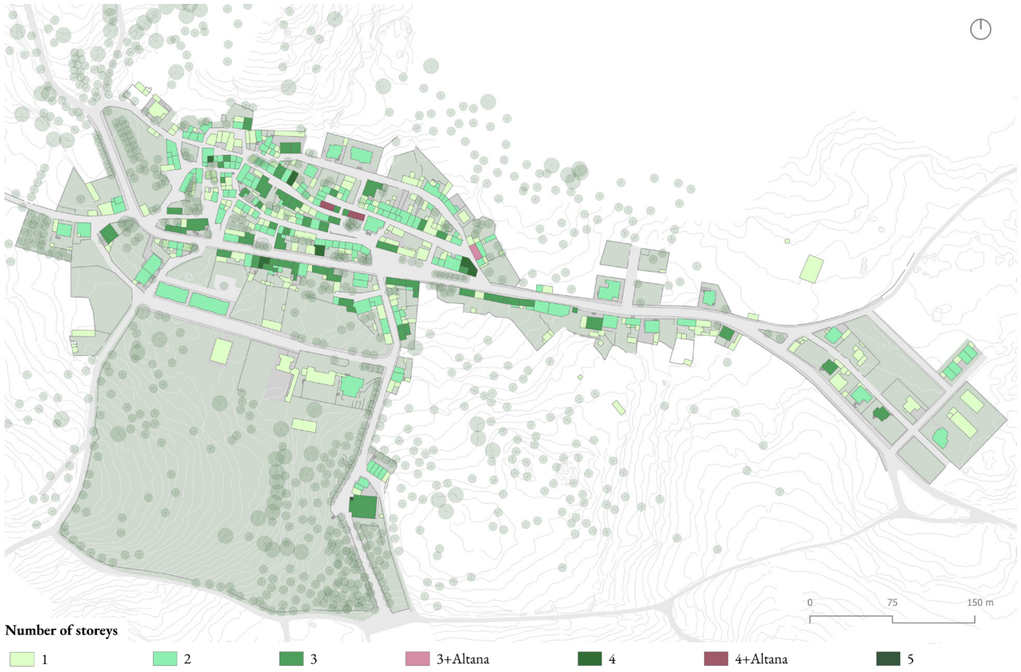
**Fig. 140 (p. 194, above)** *BUs, chronological phases of construction. Source: author's graphic elaboration from QGIS.*

**Fig. 141 (p. 194, below)** *BUs, number of storeys. Source: author's graphic elaboration from QGIS.*

**Fig. 142 (p. 195, above)** *BUs, state of use. Source: author's graphic elaboration from QGIS.*

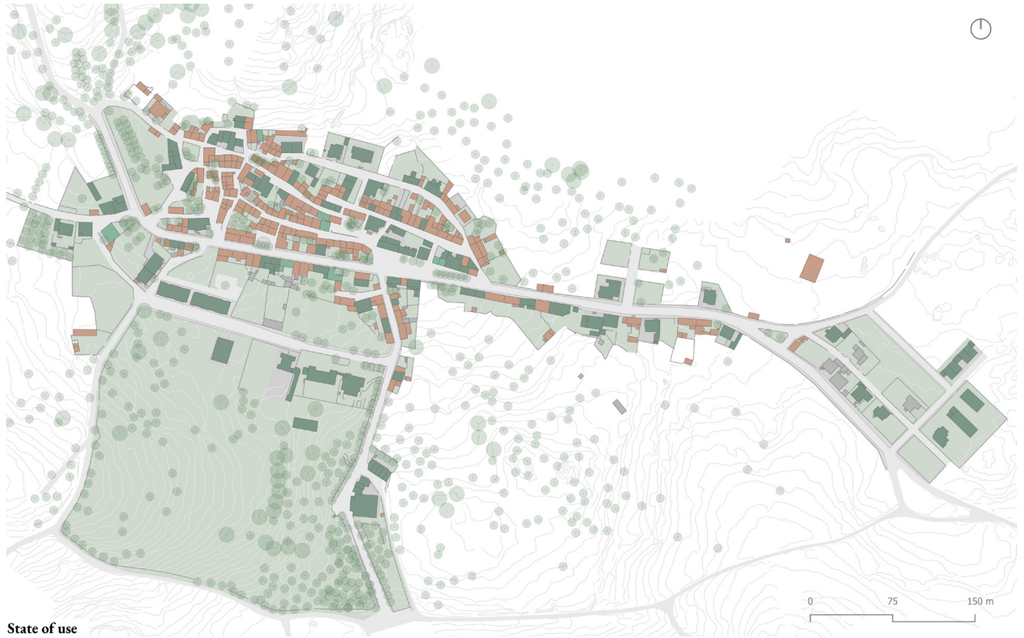
**Fig. 143 (p. 195, below)** *BUs, use designation. Source: author's graphic elaboration from QGIS.*


0
75
150 m
Chronology of construction
Pre-1849
1849–1939
1939–1960
Post 1960


0
75
150 m
Number of storeys
1
2
3
3+Altana
4
4+Altana
5






0
75
150 m
State of use
Not in use
In use
Intermittent use
Not ascertainable

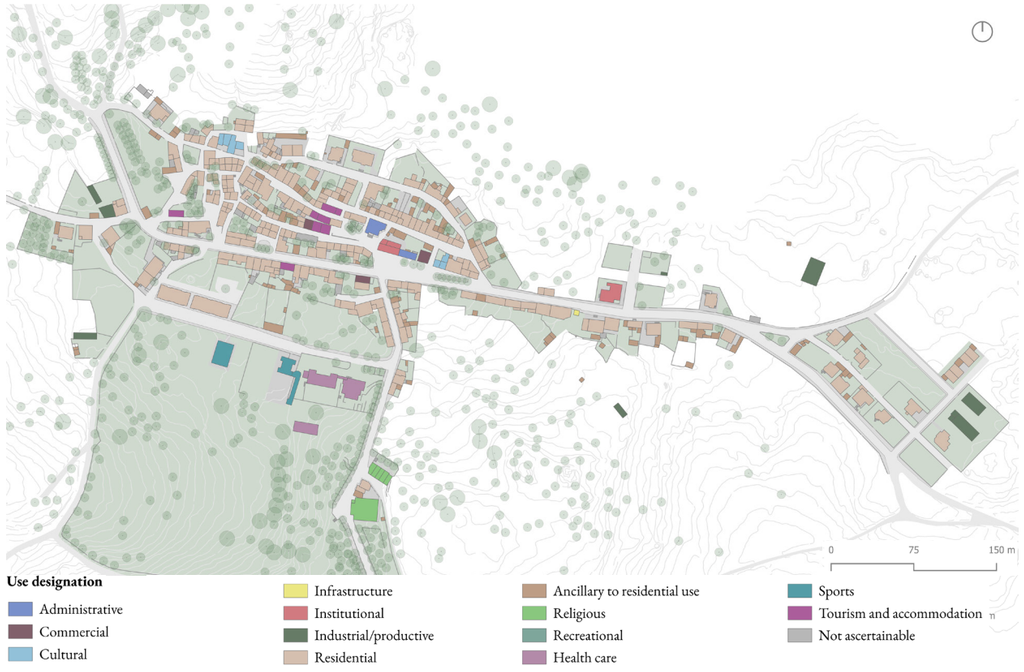

0
75
150 m
Use designation
Administrative
Commercial
Cultural
Infrastructure
Institutional
Industrial/productive
Residential
Ancillary to residential use
Religious
Recreational
Health care
Sports
Tourism and accommodation
Not ascertainable







**Fig. 144 (above)**
*An administrative building, the town hall. Source: author's photo, 2022.*

**Fig. 145 (middle)**
*A cultural building, the municipal library of Osidda. Source: author's photo, 2022.*

**Fig. 146 (below)**
*A cultural building, the ethnographic museum, 2025.*





*BUs - Building typology*

The morphological study of the buildings yielded twenty-one typological classes. Of these, ten refer to what is commonly termed traditional architecture and had already been recognised by the 2015 DPHC (Fig. 147). These are vernacular forms typical of Osidda's urban fabric (Fig. 148):

A: single-cell ground-floor unit with mono-pitch roof

B: two or more ground-floor cells with mono-pitch roof

C: single-cell ground-floor unit with gabled roof

D: two or more ground-floor cells with gabled roof

E: single-cell, two-storey unit with mono-pitch roof

F: two or more cells, two or three storeys, with mono-pitch roof

G: single-cell, two or three storeys, with gabled roof

H: two-cell, two or three storeys, with gabled roof

I: *palattu* with three or more cells, two or three storeys, with gabled roof

L: *palattu* with three or more cells, four or five storeys where an *altana* is present, with gabled roof

A further eleven types are characterised by upward extensions, enlargements, or substantial alterations to the original formal configuration, including changes to roof typology such as the conversion from pitched to flat roofs (Fig. 149, from Mt to Vt). Depending on the materials employed, these modifications can degrade the village's landscape quality and precipitate actual fabric decay, not least because they frequently arise from self-build practices and are left unfinished. Typical consequences include compromised waterproofing and drainage, thermal bridging and interstitial condensation, differential movement at junctions, and accelerated deterioration of masonry. These are designated as transformed types (Fig. 150):

Mt (Type M, transformed): single-cell unit with modern upward extensions to two or more storeys and a single-pitch roof

Nt: single-cell unit with modern upward extensions to two or more storeys and transformed roof typology

Ot: two-cell unit with modern upward extensions to two or more storeys and a single-pitch roof

Pt: two-cell unit with modern upward extensions to two or more storeys and a double-pitch roof

Qt: two-cell unit, two or three storeys, with transformed roof typology

Rt: two-cell unit, one or more storeys, with modern enlargements and a single-pitch roof

St: two-cell unit, one or more storeys, with modern enlargements and a double-pitch roof

Tt: *palattu* with modern upward extensions to two or more storeys and a single-pitch roof

Ut: *palattu* with modern upward extensions to two or more storeys and a double-pitch roof

Vt: *palattu* with three or more cells, two or more storeys, with transformed roof typology

Moreover, architectural works erected in recent decades, often displaying features incongruent with the village's traditional landscape character, were surveyed and classified as Modern Building Typology (Fig. 149, MBT). Other "out of classification" BUs are peculiar buildings such as churches.

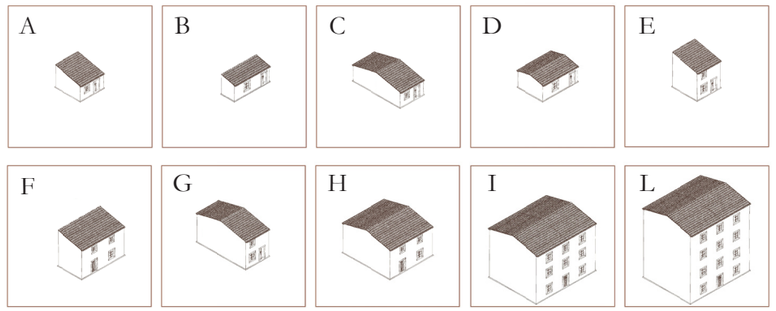
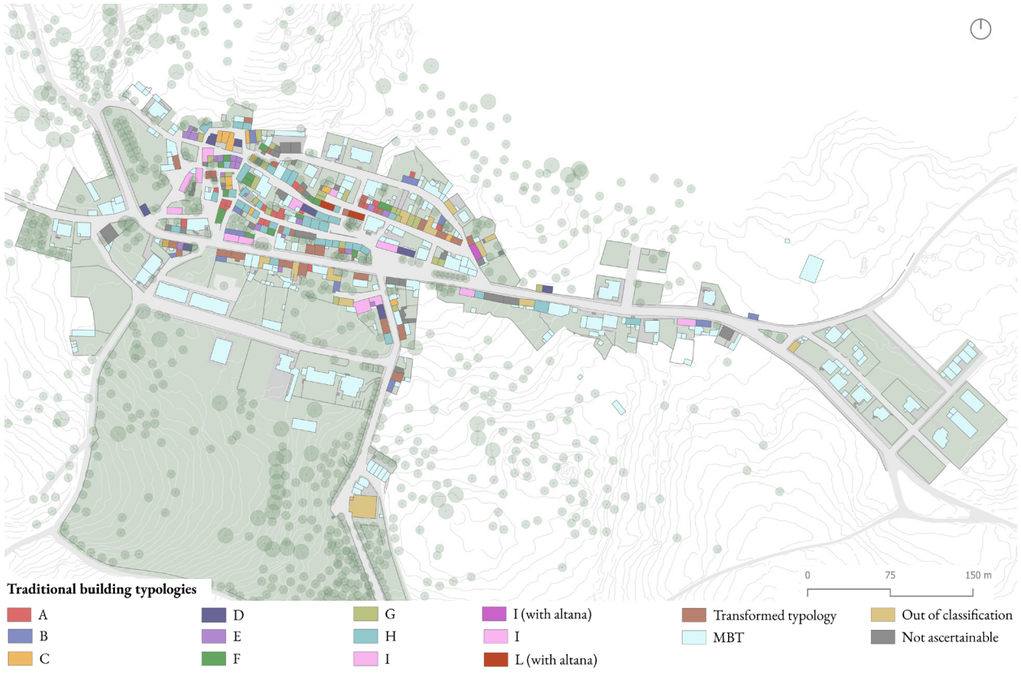



**Fig. 147 (above)**
*Traditional building typologies. Source: Municipality of Osidda 2015, plan 05.01.*

**Fig. 148 (below)**
*BUs, traditional building typologies. Source: author's graphic elaboration from QGIS.*







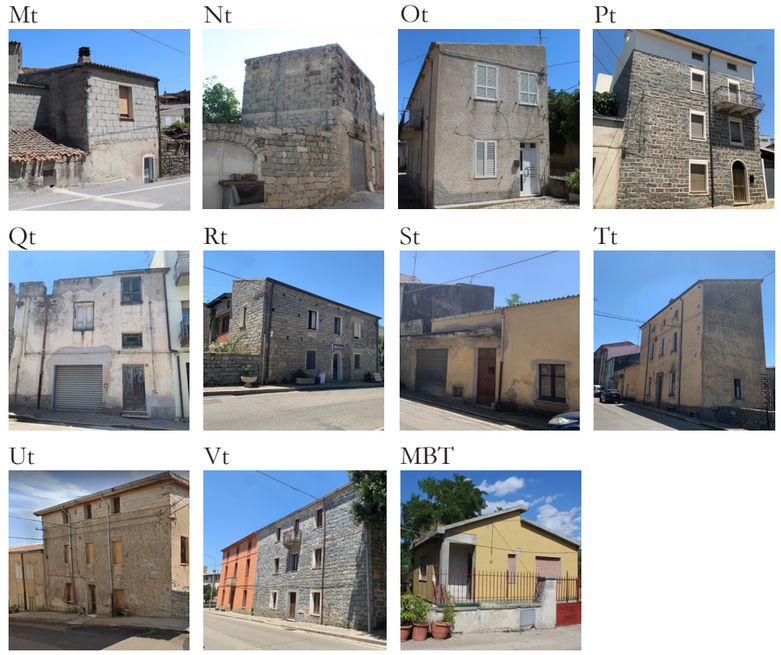
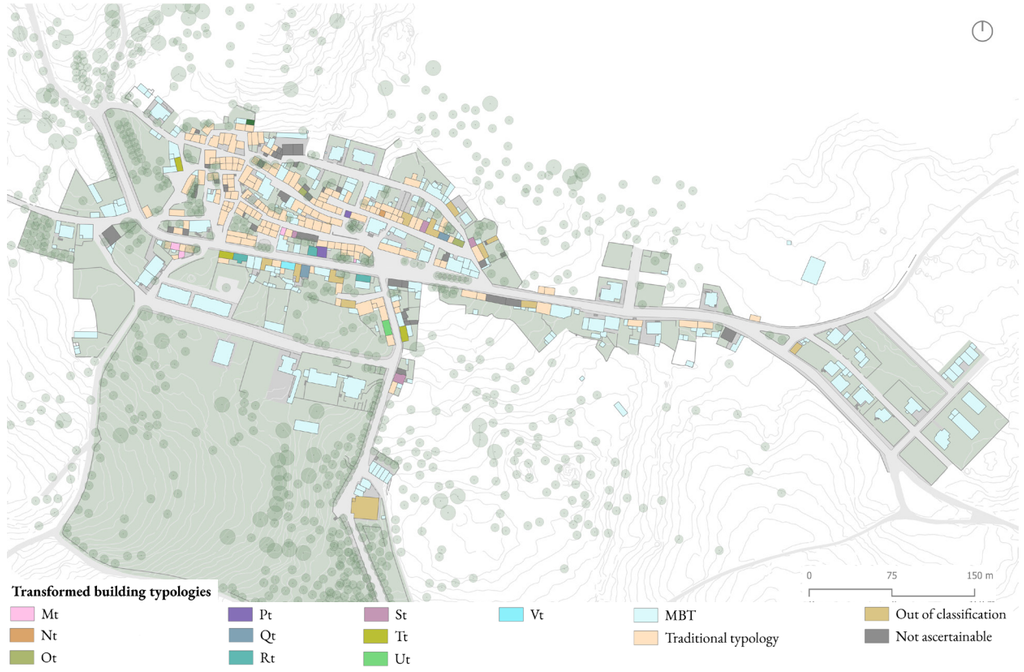




**Fig. 149 (above)**
*Transformed building typologies. Source: Municipality of Osidda 2015, plan 05.01.*

**Fig. 150 (below)**
*BUs, transformed building typologies. Source: author's graphic elaboration from QGIS.*



*BUs - Masonry construction techniques*

For the detailed study of construction techniques and components, a system of subcategories was adopted to reflect the variety of formal and functional solutions present in the village. To manage the complexity, for each subcategory an identification code was assigned, composed of the macrocategory identifier followed by the subcategory acronym, separated by an underscore. In some cases, more than one subcategory applies to the same unit because different conditions coexist.

The macro-category of masonry construction techniques was subdivided into subcategories covering three historical stone masonry (TM1, TM2, TM3; Figs. 151, 152) and two contemporary techniques such as concrete blocks (CM1; Figs. 151, 152) and reinforced concrete structure with concrete blocks (CM2; Figs. 151, 152). Other type of structures are denominated as "others". Some examples of this cathegory are a few prefabricated structures and a few characterised by modern granite masonry. Modern granite masonry is identifiable by the use of industrially squared blocks and a lighter-coloured granite than that native to Osidda, most likely sourced from nearby Buddusò, where a paler local granite is industrially tooled and commercially distributed.

The survey of traditional masonry indicated that distinct construction typologies track different stages in the specialisation of building techniques. The earliest method employed irregular fieldstones of varying shapes and sizes, laid in an earth-based mortar. Their appearance varies markedly by lithology, having been subjected to different weathering regimes that produced heterogeneous decay patterns (TM3). The variability in shape and size offered limited structural interlock, so walls required substantial thickness, often 70 cm or more. A subsequent development involved constructing two parallel wall facings, partially interlocked and filled with a mixture of earth mortar and small stones (TM2). However, the most common technique employed was the use of squared granite blocks, particularly from the 19th century onward. The length of these blocks determined the wall thickness, with the two parallel facings connected by through-stones placed lengthwise every two or more blocks (TM1). The blocks were bonded with earth or lime mortar, and the voids between them were filled with stone chips, forming what is known as "*catenelle*" (TM1, TM2)[53]. It is also common to find "waiting blocks", stones protruding from the outer edge of buildings, that indicate an intention to extend the structure longitudinally. However, such expansions were often never realised.

This category is particularly relevant for further assessment of the urban microclimate.

53 Sanna, Cuboni 2009, pp. 170-176.





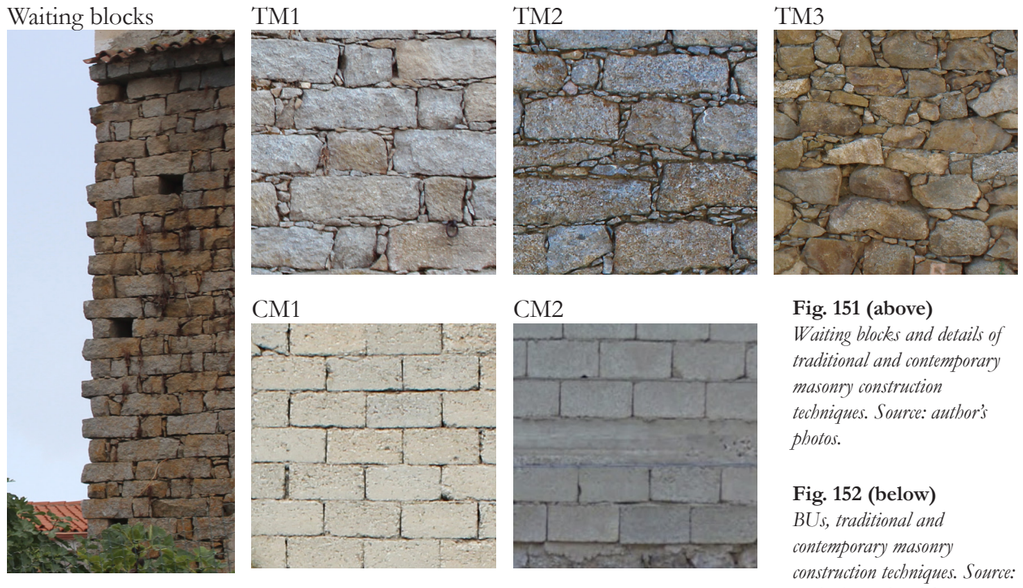



**Fig. 151 (above)**
*Waiting blocks and details of traditional and contemporary masonry construction techniques. Source: author's photos.*

**Fig. 152 (below)**
*BUs, traditional and contemporary masonry construction techniques. Source: author's graphic elaboration from QGIS.*



*BUs - Roofs*

The analysis of roof types identified traditional solutions with *coppi sardi* and *altana* (Figs. 153, 155), alongside revisions or substitutions in which traditional elements were replaced by more recent industrial tiles (Figs. 154, 155). Although these are recent replacements, such changes do not alter the traditional roof typology and need not be judged incongruous per se. More attention should be addressed to those alterations that replace traditional single or double pitch roofs with flat roofs, and those that introduce materials incompatible with the historic building fabric, such as exposed waterproofing membranes or prefabricated fibre-cement panels (Figs. 154, 155). Such interventions heighten the risk of water ingress and subsequent decay arising from UV and thermal degradation of exposed membranes, ponding and blistering, interstitial condensation with timber decay, efflorescence and freeze–thaw damage, and differential movement at junctions; they also undermine reversibility and the visual legibility of the historic roofscape. Furthermore, the nature of the roofs can impact on urban microclimate and outdoor thermal comfort. Finally, in cases where the roof has collapsed owing to abandonment and structural decay, the condition is denoted by '–'; where the roof typology can be inferred, for example from surviving elevations, it is reported in parentheses.

Roofs were classified as follows:

R_T1 (Traditional Roof 1): mono-pitch roof in *coppi*

R_T2: double-pitch roof in *coppi*

R_A1 (Roof with *Altana* 1): double-pitch roof in *coppi* with an *altana* roofed with a multi-pitch covering

R_A2: double-pitch roof in *coppi* with an *altana* having a mono-pitch roof and terrace

R_A3: double-pitch roof in *coppi* with an *altana* having a flat roof

R_C1 (Contemporary Roof 1): contemporary or replacement mono-pitch roof in industrial tiles

R_C2: contemporary or replacement double-pitch roof in industrial tiles

R_C3: contemporary or replacement multi-pitch roof in industrial tiles

R_C4: contemporary mono- or double-pitch roof in Marseilles interlocking tiles

R_C5: contemporary mono-pitch roof in incongruous materials

R_C6: contemporary double-pitch roof in incongruous materials

R_F1 (Flat Roof 1): accessible flat roof

R_F2: non-accessible flat roof

**Fig. 153 (next page, above)**
*BUs, traditional roof typologies. Source: author's graphic elaboration from QGIS.*

**Fig. 154 (next page, below)**
*BUs, contemporary roof typologies. Source: author's graphic elaboration from QGIS.*










**Fig. 155**
*Traditional and contemporary roof typologies. Source: Autonomous Region of Sardinia, n.d., oblique aerial images.*





*BUs - Eaves solutions*

The eaves-to-wall junction is a distinctive element because it integrates form and function in a feature that is emblematic of the urban fabric, expressed in multiple variants and combining different materials. Since it also serves to manage rainwater run-off, traditional eaves solutions are not planar: they form mouldings of varying projection that contribute decorative articulation to the façade. Traditionally, water disposal was often handled by specific elements that project from the roof covering, such as the so-called "channel" tiles, which in many cases preserve their historical configuration (Figs. 157, 158). In other cases a gutter was added in recent times (Figs. 157, 158). Moreover, in some traditional buildings the original roof coverings have been replaced with contemporary incongruous materials, with no provision for rainwater disposal and no detailing to ensure continuity at the roof–wall junction (Figs. 157, 158). Such conditions facilitate water ingress and accelerate material decay.
The eaves solutions were classified as follows:

ES_T1 (Traditional Eaves Solution 1): simple overhang of the roof covering with direct disposal of rainwater

ES_T2: overhang of projecting channel tiles with direct disposal of rainwater

ES_T3: overhang of the roof covering with a stone-and-mortar cordon supported by a course of *coppi* set into the masonry

ES_T4: overhang of the roof covering with two additional courses of *coppi* set into the masonry with differing projection depths

ES_T5: overhang of the roof covering with a moulded cordon

ES_T6: overhang of the roof covering supported by a corbel of squared stone elements set into the masonry

ES_T7: overhang of the roof covering formed by a corbel of brick elements set into the masonry

ES_T8: overhang of the roof covering with a brick-and-mortar cordon resting on stone elements set into the masonry

ES_T9: overhang of the roof covering with a cordon composed of alternating brick courses and stone corbels set into the masonry

ES_C1: (Contemporary Eaves Solution 1) overhang of the roof covering with a reinforced-concrete cordon projecting to a greater or lesser extent beyond the wall face

ES_G1 (Eaves Solution with Gutter 1): addition of contemporary gutter to traditional eaves systems for rainwater disposal

ES_G2: contemporary gutter

ES_I (Incongruous Eaves Solution): incongruous system due to incongruous roof covering

ES_IR (Eaves Solution with Incongruous Roof covering): traditional eaves solution paired with an incongruous roof covering



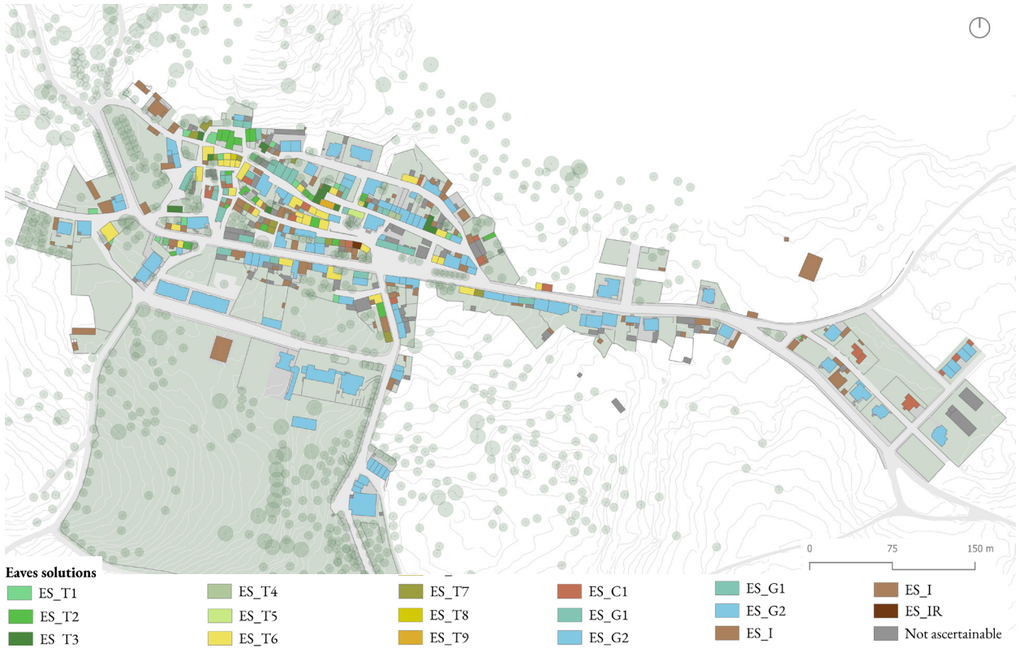










**Fig. 156 (previous page, above)**
*Urban landscape in which it's possible to identify different typologies of roofs and eaves solutions. Source: author's photo, 2025.*

**Fig. 157 (previous page, below)**
*BUs, traditional and contemporary eaves solutions. Source: author's graphic elaboration from QGIS.*

**Fig. 158**
*Traditional and contemporary eaves solutions. Source: autor's photos, 2022.*

*BUs - Opening frames*

With regard to opening frames, both doors and windows, as with roof coverings it is not uncommon to encounter replacement timber frames within traditional buildings, where older and probably decayed joinery has been substituted. Although contemporary, many of these timber replacements reproduce traditional materials, structure and components, proportions, profiles, and subdivision, and should not therefore be deemed incongruous per se. Items classified as "contemporary" refer to modern frames in more recent structures; even in these cases judgement should not be made a priori, since compatibility depends on material, structure and components, design, and placement. More attention should be addressed at the categories of metal frames, largely in anodised aluminium, and PVC frames, as they introduce risks of thermal bridges and condensation. Finally, where door and window frames have been removed or have collapsed through abandonment and decay, the condition is denoted with '–'. The window and door frames were classified as follows (Fig. 159):

FR_TT: Traditional timber frame

FR_CRT: Contemporary replacement timber frame

FR_CRM: Contemporary replacement metal frame

FR_CRP: Contemporary replacement PVC frame

FR_CT: Contemporary timber frame

FR_CM: Contemporary metal frame

FR_CP: Contemporary PVC frame

Where present, additional attributes were recorded for the type of closure system (for example roller shutters, solid shutters, louvred shutters) and for the presence of a fanlight, either rectangular or semicircular.

**Fig. 159**
*Traditional, replacement, and contemporary frames. Source: autor's photos, 2025.*

FR_TT



FR_CRT



FR_CRM



FR_CRP



FR_CT



FR_CM



FR_CP



Fanlight







*BUs - Balconies*

Historic balconies are distinguished by their combination of materials and components, for example granite corbels or wrought-iron brackets supporting a stone slab. Contemporary balconies are, by contrast, predominantly in reinforced concrete. In both groups, the classification differentiates between true projecting balconies and non-projecting simple openings used as small standing places. Contemporary examples may also appear as "continuous" balconies that extend for one entire facade or across more than one facade.
Attention to balconies is essential because incongruous materials and detailing can introduce differential thermal and moisture behaviour, create discontinuities in waterproofing, promote galvanic corrosion and rust jacking at fixings, stain and salt-load adjacent masonry, and induce cracking through incompatible stiffness, all of which accelerate fabric decay and increase maintenance burdens. They were classified as follows (Fig. 160):

B_TO: Traditional simple opening

B_TGC: Traditional granite slab on granite corbels

B_TIB: Traditional granite slab on wrought-iron brackets

B_CO: Contemporary simple opening in reinforced concrete

B_CC: Contemporary reinforced-concrete balconies

B_CCC: Contemporary continuous balcony in reinforced concrete

**Fig. 160**
*Traditional and contemporary balconies. Source: autor's photos, 2025.*

B_TO



B_TGC



B_TIB



B_CO



B_CC



B_CCC



*BUs - Ironworks*

With regard to ironwork, two principal categories are distinguished: window grilles and balustrades. In Osidda, grilles are frequently installed on windows for security purposes. Particularly where decorative motifs are present, ironworks are often hand-wrought. By contrast, some elements such as balcony balustrades in contemporary examples are typically of industrial manufacture.The ironworks were classified as follows (Fig. 160):

IW_G1: Wrought-iron grille with linear elements for a window opening

IW_G2: Wrought-iron lattice grille for a window opening

IW_G3: Wrought-iron grille with decorative elements for a window opening

IW_G4: Contemporary or replacement iron grille with linear elements for a window opening

IW_G5: Contemporary or replacement iron lattice grille for a window opening

IW_G6: Contemporary or replacement iron grille with decorative elements for a window opening

IW_B1: Wrought-iron balustrade with decorative elements for a balcony or simple opening

IW_B2: Contemporary or replacement iron balustrade with linear elements for a balcony or simple opening

IW_B3: Contemporary or replacement iron balustrade with decorative elements for a balcony or simple opening




**Fig. 160**
*Traditional, replacement, and contemporary gilles for window openings and balustrades. Source: autor's photos, 2022.*





*BUs - Wall finishes*

The surface finish is critical in traditional masonry buildings because the use of incongruous materials, such as cement-based mortars, can trigger decay. The risk is particularly acute where joints between stone units are repaired with cement in place of the traditional lime mortar or, in earlier phases, earth mortar. Incompatibilities arise from differences in vapour permeability, stiffness and thermal movement, which can concentrate stresses, drive moisture into the stone, and promote salt crystallisation and spalling. Joint treatments in such contexts include projecting joints, raked joints, and bag-rubbed finishes, each implying a specific relationship between the stone face and the joint. It should be noted that the terminology used to describe the workmanship has been adopted solely to distinguish the various types of joint treatments; however, this does not imply that the works were executed according to the best practise. Furthermore, it is important to specify that no sampling of mortars or plasters was carried out. Nevertheless, it has been hypothesised that all surface finishes were executed using cement-based materials, as suggested by their color, texture, and patterns of decay. This does not exclude the possibility that the mortar between the stones, deeper than the surface, might still be earthen or lime-based.

In Osidda, as in many historic villages, renders and finishes have often been selected for cost and ease of procurement rather than compatibility. Surfaces are frequently non-uniform, since additions or alterations in the wall fabric, for example wall areas rebuilt in concrete blocks, are plastered to conceal contemporary portions. This practice can produce "patchwork" finish effects. A typical case occurs where a former granite boundary wall, once part of an open ancillary space, is incorporated into a closed contemporary construction. In Sardinia it is also common for surfaces to be left unfinished (the so-called "Sardinian unfinished"[54]), since construction is often considered complete once it fulfils the functional need of enlarging domestic space; surface finish is therefore treated primarily as an aesthetic choice rather than a protective layer. From a conservation standpoint, however, finishes should be specified for material compatibility and moisture management, not only for appearance. Moreover, they are particularly important for their impact on urban microclimate and outdoor thermal comfort.

They are classified as follows (Figs. 161, 162):

FI_BS: Bare stone facing (stone or cement blocks)

FI_PJC: Projecting joints (pointing standing proud of the masonry face) finished with cement mortar

FI_RJC: Raked joints (pointing raked back from the masonry face) finished with cement mortar

FI_BRC: Bag-rubbed finish (slurry of plaster rubbed over the masonry to fill joints and part of the stone face) with cement plaster

54 On the topic see for example Monsù Scolaro 2024.

FI_CP: Cement plaster, unpainted

FI_CPP: Cement plaster, painted

FI_CPPW: Cement plaster, partially painted (patchwork)

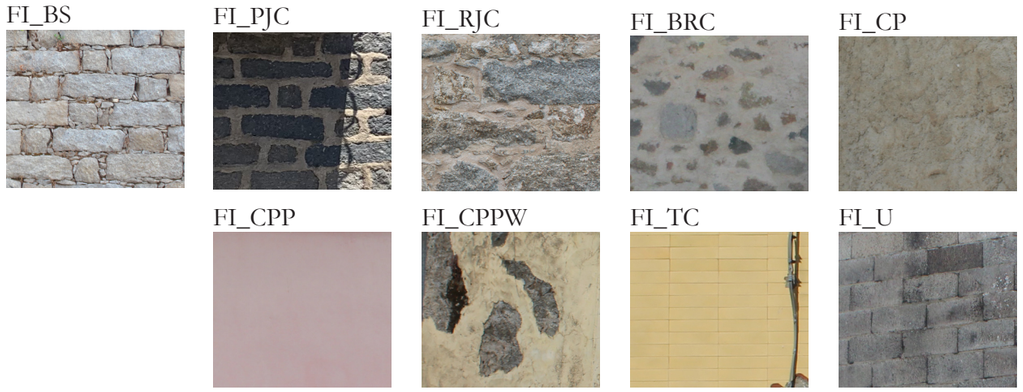
FI_TC: Tiled cladding

FI_U: Exposed masonry facing (unfinished)

**Fig. 161 (above)**
*Wall finishes.*
*Source: autor's photos, 2022.*

**Fig. 162 (below)**
*BUs, wall finishes.*
*Source: author's graphic elaboration from QGIS.*

It's important to note that the map indicates the prevailing finish for each building, but side or behind elevations often have a different finish, as well as it often happens with enlargements or upper storeys.











*BUs - Distinctive architectural elements*

The village's distinctiveness is also legible through a set of architectural components that strongly characterise the local landscape and function as identity markers. These were recorded under the specific category of distinctive architectural elements. They include: timber or granite lintels; monolithic stone reveals, arches, and lintels; *cappuccine*; moulded mortar surrounds to door and window openings (Fig. 163); arched doors and gateways (Fig. 164); *altane* on the roofscape (Fig. 165).

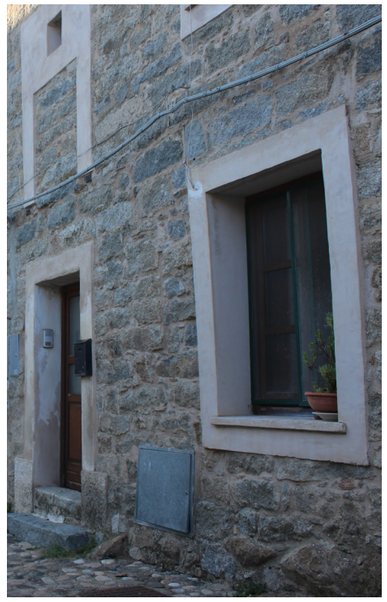






**Fig. 163 (above, left)**
*Moulded mortar surrounds to door and window openings.*
*Source: autor's photos, 2025.*

**Fig. 164 (above, right)**
*Monolithic stone reveals and arch.*
*Source: autor's photos, 2025.*

**Fig. 165 (below)**
*An altana seen from the inside.*
*Source: autor's photos, 2025.*

*BUs - Retention of original fabric index*

The Retention of original fabric index was introduced to indicate the proportion of original material and components surviving in traditional buildings (Fig. 166). The indicator is intended to reflect the extent of remodelling and alteration undergone by the structure. It was applied on a numerical scale:

0 - BU entirely lost

1 - Only vestiges of original masonry remain (e.g., short stretches or basal courses; all other parts replaced)

2 - Extensive substitutions or transformations (e.g., substantial wall sections, roof structures)

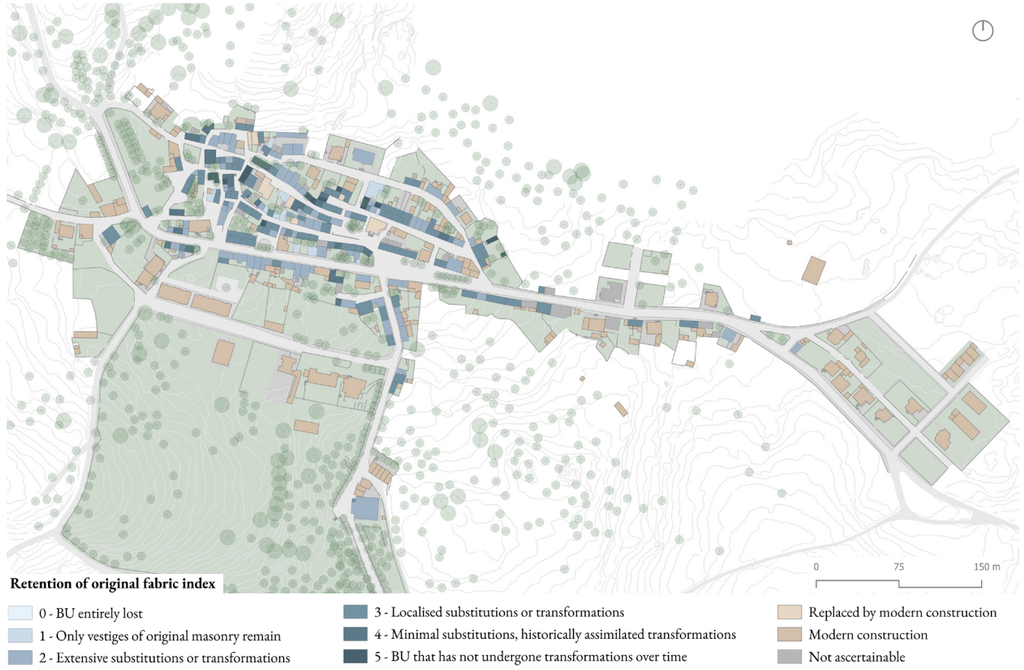
3 - Localised substitutions or transformations (e.g., frames, small wall portions)

4 - Minimal substitutions, historically assimilated transformations (the organism was altered in earlier periods and the changes have acquired heritage value)

5 - BU that has not undergone transformations over time

This parameter also provides an entry point for subsequent stratigraphic analysis.

**Fig. 166**
*BUs, retention of original fabric index. Source: author's graphic elaboration from QGIS.*








*BUs - Overall conservation status*

The final theme for BUs concerns the overall condition of each unit, assessed holistically with reference to all constituent elements (Fig. 167). The indicator was applied on a numerical scale:

0 - Ruins; structures in a ruinous state

1 - Moderate to severe structural distress (structural damage to the load-bearing system with potential for settlement or collapse) and/or unfinished structure

2 - Advanced decay associated with rainwater infiltration, rising damp, and widespread surface wash-off (extensive decay of finishes with potential for building fabric damage, such as efflorescence and salt crusts, detached or hollow plasters, staining from defective rainwater goods)

3 - Slight deterioration of surfaces and/or the presence of anthropogenic alterations (superficial degradation not affecting the building fabric, such as extensive cement rough coats on the façade or areas of biological colonisation)

4 - Localised areas of decay linked to specific environmental or anthropogenic agents (e.g., localised masonry damage caused by fixings, small rough-coat patches, and areas of render detachment or delamination)

5 - Minor anthropogenic interferences only (e.g., the presence of wires on the facade)

6 - No observable pathology of decay

**Fig. 167**
*BUs, overall conservation status. Source: author's graphic elaboration from QGIS.*



*Public spaces - Paving materials*

With regard to public space, no identification codes were assigned to subcategories, since the level of complexity is considerably lower than for the BUs. The first theme comprised a survey of paving materials, identified as follows (Figs. 168, 169): cobbles; granite slabs; stone setts (*sanpietrini*); concrete; concrete tiles; and bituminous conglomerate (asphalt). As previously noted, among the surveyed materials the only historic paving documented in Osidda is cobblestone. The nature and characteristics of paving materials are among the most influential factors on urban microclimate and can be crucial for outdoor thermal comfort.

**Fig. 168 (above)**
*Paving materials. Source: autor's photos, 2022.*

**Fig. 169 (below)**
*Public space, paving materials. Source: author's graphic elaboration from QGIS.*

Cobbles



Stone setts



Concrete tiles



Granite slabs

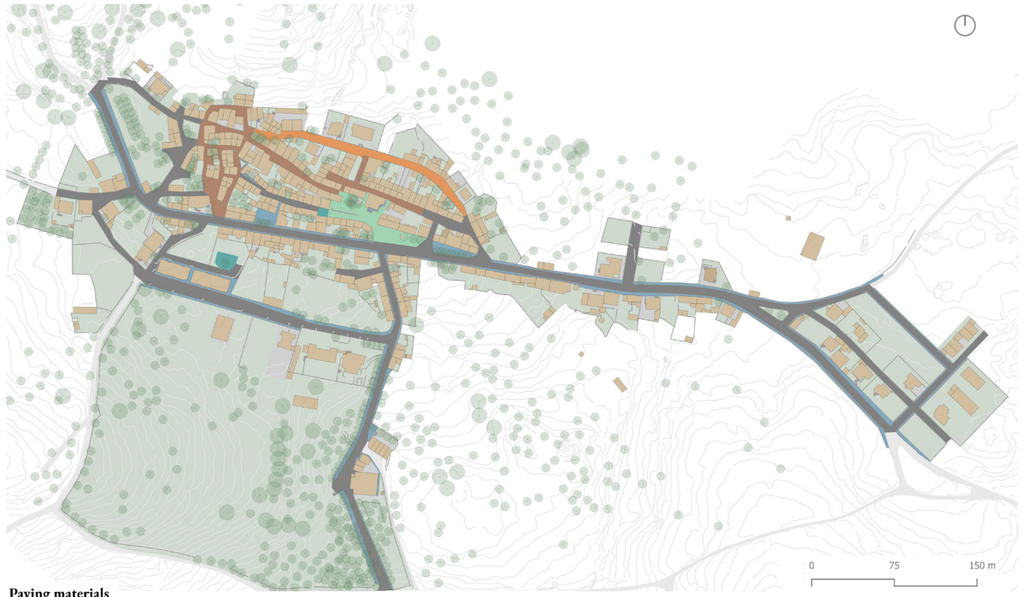


Concrete



Asphalt










*Public spaces - Urban furniture*

A survey was undertaken of urban furnishings, including benches (monolithic stone blocks or stone slabs on stone supports), planting and flower beds, and street lighting fittings (wrought-iron wall-mounted lamp, wrought-iron lamp post, and gooseneck streetlight). Also retaining walls, footways, and stairs have been drawn and are represented as lines in the map (Figs. 170, 171).
Recording these elements supports an integrated reading of public-space character, as they not only influence perception and use of the public space, but also impact on accessibility and circulation, drainage and surface durability, night-time safety and heritage imageability, and they can introduce incongruities if materials and forms are at odds with traditional fabric. Especially in the case of the wall-mounted lamps, the presence of these elements could produce degradation in the building fabric.

**Fig. 170 (above)**
*Urban furniture. From left to right: wroguht-iron lamp post, wroguht-iron wall-mounted lamp post, flower bed, type 1 benches, and outdoor stairs. Source: autor's photos, 2022.*

**Fig. 171 (below)**
*Public space, urban furniture. Source: author's graphic elaboration from QGIS.*



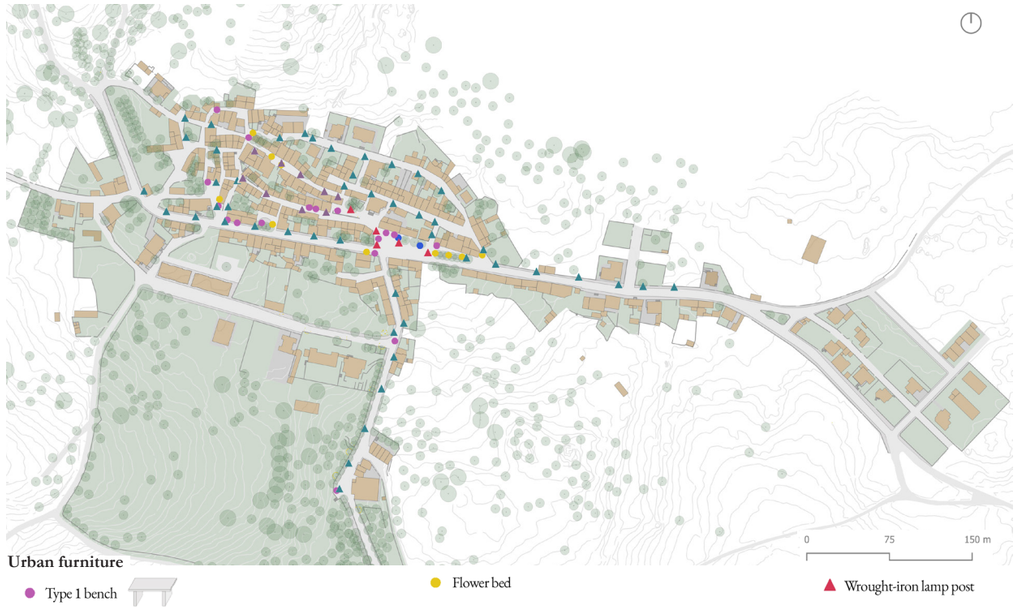












*Public spaces - Retention of original pavement index*

In this case, the retention of original pavement index expresses the proportion of original materials and components surviving in traditional pavements. As noted for Osidda, the only traditional pavement that survives is cobblestone, so the index will display limited variability. This does not imply that all modern pavements within the village are incongruous or should be replaced; their compatibility should be judged with reference to additional factors such as condition, material composition, permeability, and visual impact, along with impacts on the outdoor thermal comfort. For public spaces, similarly to BUs, the index is structured as follows (Fig. 172):

0 - Traditional pavement entirely lost

1 - Only vestiges of original pavement remain

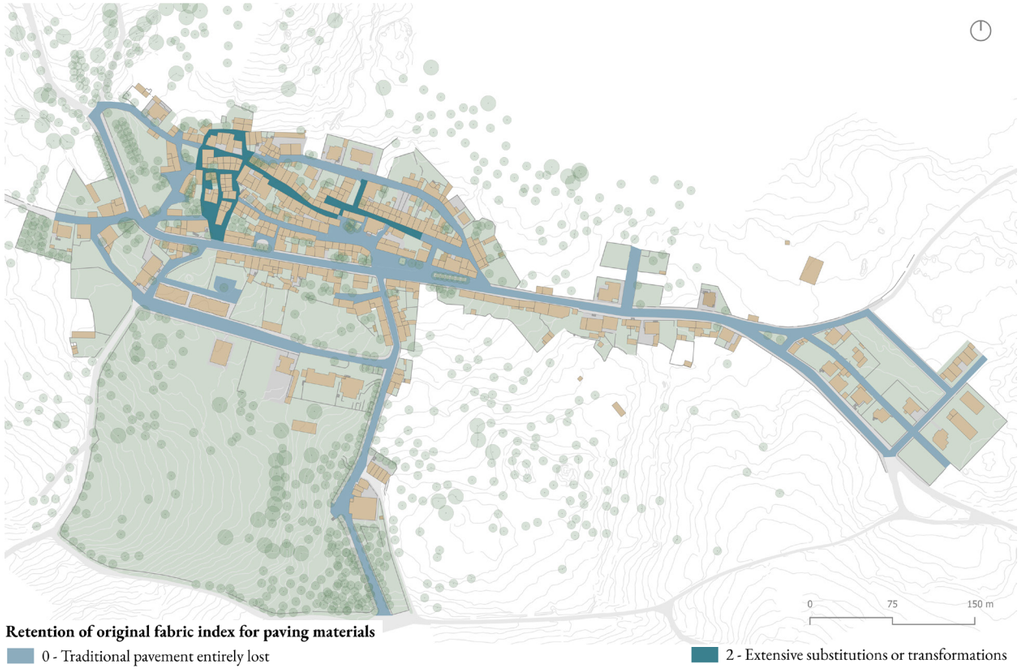
2 - Extensive substitutions or transformations

3 - Localised substitutions or transformations

4 - Minimal substitutions, historically assimilated transformations

5 - BU that has not undergone transformations over time

**Fig. 172**
*Public space, retention of original fabric index. Source: author's graphic elaboration from QGIS.*








*Public spaces - Overall conservation status*

The final theme for public spaces concerns the overall condition, assessed holistically with reference to pavements and urban furniture. The indicator was applied on a numerical scale (Fig. 173):

0 - Space lost or unusable (eradicated or obstructed public space)

1 - Severe structural or safety failure (instability, major pavement collapse)

2 - Advanced decay with functional failure (widespread potholes, heave from roots, extensive spalling or delamination of surfacing)

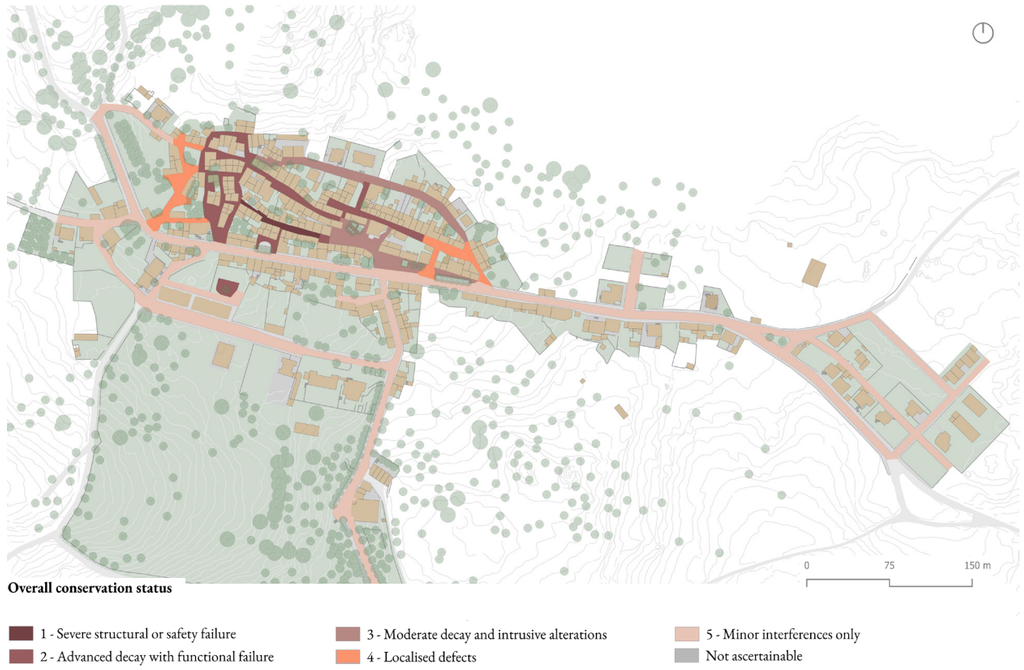
3 - Moderate decay and intrusive alterations (discontinuous joints, local ponding, open joints around utility covers, widespread biological colonisation creating slipperiness, extensive repairs with non-compatible materials)

4 - Localised defects (isolated cracked slabs, punctual repairs with non-compatible materials)

5 - Minor interferences only (surface staining, minor vegetation encroachment)

6 - No observable pathology

**Fig. 173**
*Public space, overall conservation status. Source: author's graphic elaboration from QGIS.*



*Entire area of interest - Altitude profile of the terrain*

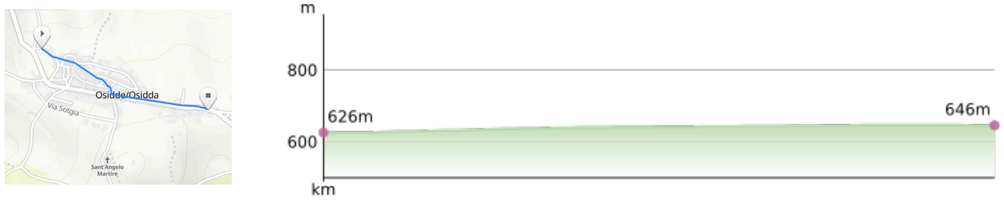
As already noted, the terrain elevation profile was derived from a Digital Terrain Model (DTM) obtained from the official Geoportal of the Autonomous Region of Sardinia. The ground surface shows no pronounced breaks in slope; rather, it rises gradually, approximately from west to east (Fig. 174).

*Entire area of interest - Impervious and permeable surfaces*

A map that separates impervious and permeable surfaces in the case study sets a clear baseline for hydrology and microclimate. It shows where sealed areas potentially concentrate run-off, limit infiltration, and raise surface temperatures. It also highlights permeable areas that support infiltration and local cooling. This evidence is crucial for the microclimatic analysis and modelling that will follow (Fig. 175).

**Fig. 174 (above)**
*Terrain elevation section and key plan.*
*Source: printmaps.net.*

**Fig. 175 (below)**
*Entire area, impervious and permeable surfaces.*
*Source: author's graphic elaboration from QGIS.*











*Entire area of interest - Vegetation and soil nature*

The vegetation survey was undertaken mostly in the area of the historic centre and surroundings, on the basis of information contained in the Municipality's Civil Protection Plan, which reports that:

"*The vegetational situation of the Municipality of Osidda is rich in elements characterising the thermomediterranean belt* […]. *The territory falls within the mesophilous horizon of the Quercus ilex forest. The areas present within the indicated horizon are characterised by a climatic type that represents an intermediate condition between a typically two-season climate, with a moderately cold and sub-humid winter, a considerable winter water surplus, and hot summers with a substantial deficit. A clear climatic indicator of this condition is the presence of species typical of the climax series of holm oak forests, such as Viburnum tinus L., Ruscus aculeatus L., Phillyrea latifolia L., the absence of thermoxerophilous coastal species, and the occasional presence in wet areas of some elements of the belts with Quercus pubescens and Quercus–Tilia–Acer, and in drier areas of Pistacia lentiscus and Olea oleander [sic].* […] *The vegetational aspect of the Osidda countryside appears to be characterised by subdivision into two main vegetational types. In the strictly hilly part of the territory, woodland formations with a prevalence of Q. pubescens predominate. The flatter part of the territory, located upstream of the axis of the Tirso and Cogorotti streams and including the settlement, is characterised by the presence of surfaces with a prevalence of arable land and artificial meadows interspersed with areas of natural pasture. In a good part of these formations the presence of Q. suber formations is noted, with a density sometimes such as to constitute true cork-oak woods*"[55].

In addition, a further verification was carried out using the Regional Environmental Forestry Plan, which reports that cork oak species are present within the municipal territory of Osidda[56]. A more specific examination of individual plants in and around the settlement, however, did not identify cork oaks; instead, the dominant taxa include downy oak (*Quercus pubescens*, deciduous broadleaf, found especially in peri-urban areas), conifers of the Pinaceae family (particularly near the church of Sant'Angelo), fig (also growing on building ruins and in the abandoned urban green areas), and evergreen oaks of the genus *Quercus* (mainly within the settlement), along with other deciduous broadleaves not identified to species, a few white poplars towards the rural fringe, some fruit trees, olive, vine, mimosa, and oleander.

The species present in Osidda were analysed using recent photographic documentation and by comparing observed traits with the known characteristics of taxa typical of the area (Figs. 176, 177). Google Street View, the Google Maps function that provides street-level imagery, proved useful for verifying whether plants were deciduous, since it allowed comparison of images from winter and summer months.

The natural soil type was also identified on the basis of the Municipality's Civil Protection Plan, "*the greater part of the municipal territory consists of soils of the types Typic, Dystric and Lithic Xerorthents, and Typic, Dystric and Lithic Xerochrepts, with*

55 Municipality of Osidda 2012, Report [*Relazione*], p. 6.

56 Autonomous Region of Sardinia 2007, Attachment 2.

**Fig. 176 (above)**
*Trees in the historic centre of Osidda and surroundings. Source: author's photos, 2025.*

**Fig. 177 (below)**
*Entire area, trees species and height. Source: author's graphic elaboration from QGIS.*

*rock outcrops*"[57]. These designations refer to soil classification, not to a single texture class. Local textures range from sandy or loamy horizons to finer subsoils depending on depth and parent material. In this case, the local soil has been identified with a sandy clay texture, which typically combines the drainage and graininess of sand with the plasticity and water-holding capacity of clay.

57 Municipality of Osidda 2012, Report [*Relazione*], p. 6.

Downy oak



Holm oak



Fig tree






## 5.3.2 The Stratigraphic Analysis

Each polygon representing a Building Unit (BU) in QGIS was attributed with a base elevation and an eaves elevation, so that the system could compute building height[58]. Both values were estimated from the photographic record and the observed number of storeys, then cross-checked against the street-profile data available in the 2015 Detailed Plan of the Historic Centre[59]. This procedure produced an initial three-dimensional model that serves as the geometric basis for the stratigraphic analysis.

The stratigraphic analysis builds on considerations already developed during the construction of the local GIS and the compilation of thematic layers, including the chronology and the retention of the urban fabric index. Absolute dating features are largely absent, since most buildings are residential and lack specific documentation on construction, alterations, or demolition. The analysis therefore relies primarily on cadastral maps from 1848, 1939, and 1960 (Figs. 178, 179, 180), complemented by the photographic campaign carried out during field surveys. The analysis concentrates on the historic centre, since areas beyond it are not represented in the reference historical cadastral maps. Sometimes, historical photos also helped with the identification of the oldest parts of the buildings (Fig. 181).

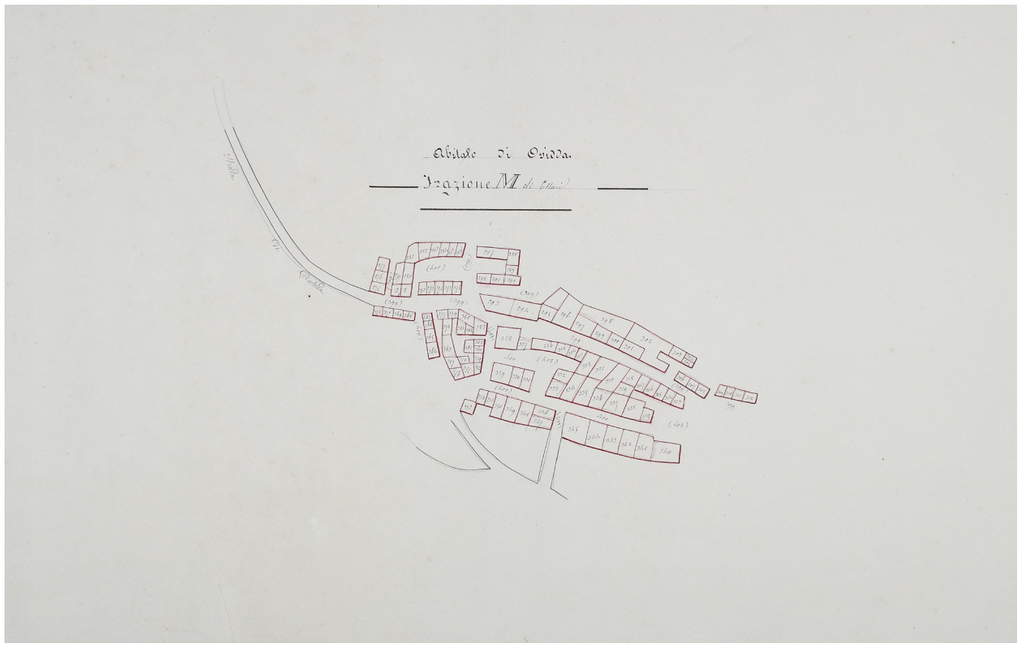
The earliest maps, read together with the chronology, indicate that the western part of the settlement preserves an archaic mode of building and inhabiting. Blocks appear to have formed organically through the aggregation of units belonging to the same family, which shared adjacent open spaces as common areas for social and domestic life. In the 1848 map these spaces correspond to the blocks surroundin the public spaces indicated with the numbers 399, 400, and 401. The retention of the urban fabric index, compared with the 1939 sheet, shows that many of those units were later modified or disappeared, leading to a change in the urban pattern[60].

Already in 1848 the settlement's evolution tends towards linear development along the present-day Via Mazzini (indicated as Via Asproni in the 1939 map) and Via Roma. This dynamic underpins the eastward expansion observed during the second half of the nineteenth century. For the purposes of this study, 1939 is adopted as the principal baseline: the settlement form is much closer to the contemporary layout and the 1939 sheet is geometrically more accurate than the 1848 one. The 1960 map is taken as the second reference because, after that date in Osidda, modern materials such as concrete appear and traditional construction techniques are progressively abandoned. The two reference cartographic maps are therefore 1939 and 1960.

58 The BUs layer was duplicated in order to maintain two separate datasets: one that records Building Units and another that records three-dimensional stratigraphic units, which do not necessarily coincide.

59 Municipality of Osidda, 2015, plan 4.

60 These information were confirmed by interviews with the community.







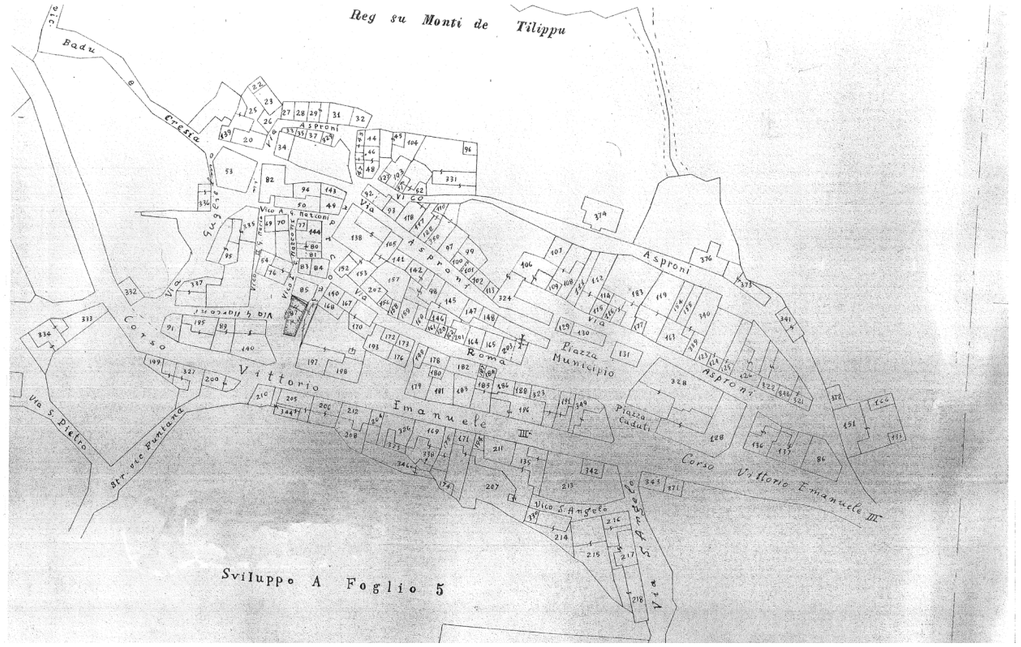






**Fig. 178 (previous page, above)**
*Historical cadastral map 1848.*
*Source: AS-NU 1848.*

**Fig. 179 (previous page, below)**
*Historical cadastral map 1939. The coloured polygons correspond to built units, while white ones correspond to open spaces. Source: AS-NU 1939.*

**Fig. 180 (above)**
*Historical cadastral map 1960. Source: Municipality of Osidda 2015, plan 1, attachment 2.*

**Fig. 181 (below)**
*Buildings in the historic centre in 1963. Source: Municipal library of Osidda.*

For the building stock of Osidda, three chronological bands are defined for three-dimensional stratigraphic units:

• Before 1939: this phase includes all units that appear in the 1939 map and display historic material and formal characteristics, such as granite masonry and features typical of vernacular architecture. Individual construction elements are examined for shape and workmanship to detect components that may have been produced industrially, hence of more recent date. Conservation state is also considered, since prolonged exposure to weathering typically results in chromatic alterations and biological patinas. Analysis of the three-dimensional building organism frequently reveals discontinuities in masonry between stratigraphic units that are otherwise similar or that are attributable to a period prior to 1939. In some buildings, two traditional techniques coexist within the same organism, one for the original nucleus (generally represented by the ground floor and sometimes the first floor) and one for a subsequent enlargement, both predating 1939. For this reason, the band "before 1939" is subdivided into Part I and Part II, distinguishing two successive construction phases whose precise dating remains unknown. This finer subdivision is applied only where vertical extensions or enlargements are particularly evident and where discontinuities have not been concealed by later units or surface finishes, hence in a limited number of cases (Fig. 182);

• After 1939 and before 1960: this phase includes units that do not appear in the 1939 sheet but are present in the 1960 sheet, and that still exhibit traditional material and formal characteristics. Many three-dimensional roof units also fall into this band. Roofs are treated as stratigraphic units distinct from walls, since they are often replaced over time even when executed with traditional materials. Roofs are assigned to the pre-1960 band when they show traditional Sardinian *coppi* and lack industrial components, given that widespread use of modern manufactured tiles and incongruous materials such as prefabricated fibre-cement panels generally post-dates 1960;

• After 1960: this band comprises all three-dimensional units absent from both the 1939 and 1960 sheets that were constructed after 1960, as well as post-1960 additions to earlier buildings. These units are typically characterised by modern materials such as concrete blocks (Figs. 183, 184) or reinforced concrete. In some cases traditional granite techniques persist, although with non-local stone types, visible in colour differences, and with industrial cutting that contrasts with artisanal workmanship. Roofs made with modern materials are also included in this band, as well as several roofs executed with traditional techniques in the 1990s, within the framework of documented restorations undertaken within the LEADER I and LEADER II programmes[61] (Fig. 185).

61 The documents were courteously supplied by the Municipality of Osidda.





The workflow followed these steps:

**1.** Selection of a target block for detailed analysis;

**2.** Map and chronology review in order to establish the period of initial layout of the anaysed block and to check whether current BUs correspond to the footprints represented in historical sheets or whether discrepancies exist;

**3.** Unit-by-unit review of photographic documentation, including oblique imagery from the Sardinian Regional Geoportal, to identify three-dimensional stratigraphic units. Material, constructional and formal features, as well as conservation state, are examined to detect differences and discontinuities that delineate distinct stratigraphic units. Examination of the lateral façades was especially useful because they are frequently left unfinished or remain unpainted, showing the nature of the fabric;

**4.** Identification of the three-dimensional units footprints and comparison with each BU footprint to detect inconsistencies. Current BUs may result from aggregation or fragmentation of earlier BUs that once formed a single organism; likewise, subsequent extensions are recorded as stratigraphic units distinct from the original organism. In the case of discrepancies, the the polygons within the GIS database are modified accordingly;

**5.** The three-dimensional stratigraphic units above ground level were drawn by duplicating the BU footprint as many times as there are stacked units within



**Fig. 182**
*Masonry discontinuities in historic buildings with different traditional construction techniques or differences in fabric degradation. Source: author's photos, 2025.*

**Fig. 183 (above)**
*Modern additions to historic buildings. Source: author's photo, 2025.*

**Fig. 184 (below)**
*Modern additions to historic buildings revealed by their rear unfinished side. Source: author's photo, 2025.*






the building organism. Each polygon copy was assigned a base elevation and an eaves elevation, so that the vertical extent of each unit could be defined. To model two superposed units, for example, the eaves elevation value of the lower unit must coincide with the base elevation value of the upper unit;

**6.** Comparative assessment of units to infer stratigraphic relationships of simultaneity or posteriority;

**7.** Assignment of units to the corresponding chronological phase according to their observed characteristics and their presence or absence in the 1939 and 1960 reference maps.

Through QGIS layer styling it is possible to define two modes of visualisation. The first renders the current state (Fig. 186). The second applies attribute-based filters to visualise selected polygons, hence units, that belong to specified categories. In this study the second mode was configured to





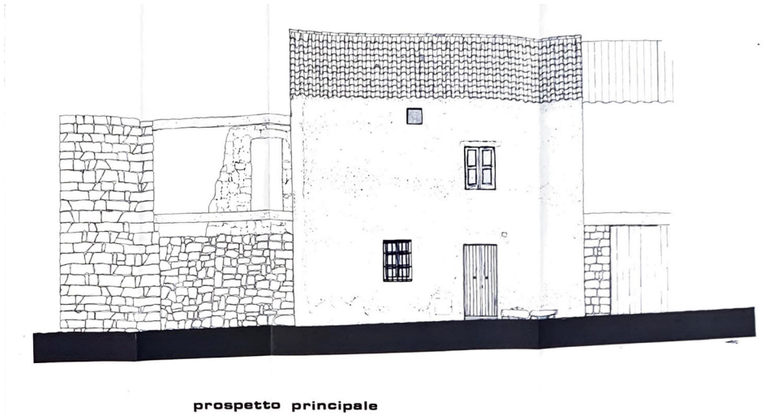



**Fig. 185**
*Traditional buildings in Via Roma, before and after the intervention with LEADER programme funds by the architect Tatiana K. Kirova. Source: Municipality of Osidda, 1990s.*

**Fig. 186 (next page, above)**
*Chronological phases of the stratigraphy in the current urban morphology. Source: author's graphic elaboration from QGIS.*

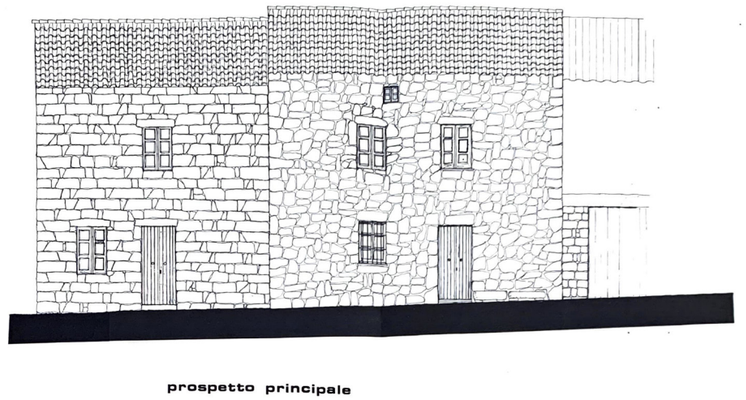
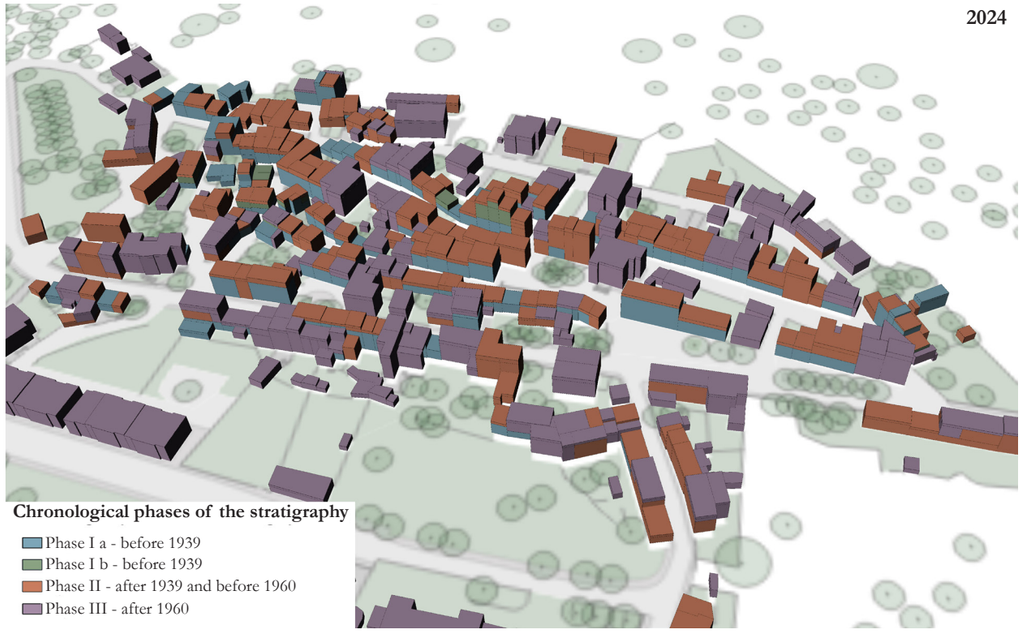



**Fig. 187 (next page, below)**
*Chronological phases of the stratigraphy in the 1939 urban morphology. Source: author's graphic elaboration from QGIS.*

display the settlement as in 1939, the chosen reference year when traditional construction techniques still predominated. Concretely, only the phase "before 1939", including its two parts, is shown, while the two later bands are hidden (Fig. 187).
In some instances a unit documented in the past has been demolished or collapsed and later replaced by a different unit, sometimes with a different footprint. Roofs have often been substituted as well. For the 1939 visualisation additional polygons were therefore created that appear only in that scenario. These polygons represent units that existed in 1939 but were subsequently destroyed, as well as roofs documented for 1939. This arrangement allows direct comparison between the 1939 settlement and its present configuration. The resulting scenario models provided the geometric basis for comparative microclimatic simulations, enabling a like-for-like assessment of differences between the two evolutionary moments of the settlement.











### 5.3.3 Results and Interpretation of the GIS-based Analysis

Chronological analysis, cross-checked against historical cadastral maps, confirms that Osidda's original compact urban structure remains largely intact. This continuity, together with the vitality of the local community and the commitment of the municipal administration, underpins Osidda's recognition as an Authentic Village within the Italian Network of Authentic Villages (*Rete dei Borghi Autentici d'Italia*)[62]. At the same time, many voids that once existed at the settlement margins and within blocks, formerly open yards, have been infilled with new buildings. As shown by the stratigraphic reading, the built volume has therefore increased both through land take and through the vertical or lateral accretion of existing BUs, often using incongruous materials. Although some traditional traits endure, such as singular architectural details and eaves solutions, recent building modifications with concrete blocks or reinforced concrete, often left unfinished, contribute to the erosion of the traditional urban landscape and to the loss of traditional know-how. As the use of customary techniques declines, construction knowledge is progressively disappearing, mirroring trends observed in many Sardinian villages. Alterations affect not only whole buildings through accretions, but also components such as roofs and opening frames.

The survey of construction techniques identifies three main typologies, whose location can be compared with the overall state of conservation map. The oldest traditional methods (TM2 and TM3) are frequently associated with heterogeneous weathering and, in some cases, collapsed sections, reflecting their structural weakness and age. By contrast, the most robust and prevalent granite technique (TM1) has proved more durable: many walls built with TM1 survive, showing only surface degradation attributable to prolonged exposure to the atmosphere or cement fixing (Fig. 188). Widespread application of cementitious plaseters, however, has introduced incompatibilities with the historic substrate, producing extensive detachment and worsening moisture problems (Figs. 189, 190) with consequent biological patinas and vegetation growth (Fig. 191). In numerous instances surface degradation, compounded by abandonment, lack of maintenance, and roof failures (Fig. 192), have precipitated structural collapse (Fig. 193).

A comparison of the retention of the urban fabric index with the overall conservation status map reveals a recurrent pattern: older, less altered structures tend to be in poorer condition, whereas many traditional buildings that have undergone substantial transformations, often for functional adaptation or reinforcement, are generally better preserved. This suggests a correlation between usability and preservation: buildings adapted to evolving needs, even where interventions are not fully consistent with the historic fabric, have benefited from sustained maintenance that has supported their survival.

62 Osidda's inclusion in the Italian Network of Authentic Villages (*Rete dei Borghi Autentici d'Italia*) was notified by letter dated 22 November 2021 (protocol no. 6683/21).













**Fig. 188 (left, above)**
*TM1 construction technique wall. Source: author's photo, 2025.*

**Fig. 189 (right, above)**
*Painting detachment in a granite wall with cement plaster. Source: author's photo, 2025.*

**Fig. 190 (right, middle/up)**
*Plaster detachment in a granite wall. Source: author's photo, 2025.*

**Fig. 191 (right, middle/down)**
*Biological patinas and vegetation growth on a granite wall with cement finish. Source: author's photo, 2025.*

**Fig. 192 (left, below)**
*Traditional roof structural failure. Source: author's photo, 2025.*

**Fig. 193 (right, below)**
*Collapsed structure and vegetation growth. Source: author's photo, 2025.*





Nevertheless, considering the whole settlement, buildings constructed wholly or partly with traditional masonry constitute nearly half of the stock; among these, more than one-third exhibit advanced and structural decay (Fig. 194). The map of use shows many houses occupied only seasonally by owners residing elsewhere, or entirely vacant, consistent with depopulation trends. Thus, the outlook on conservation is adverse, as most such buildings are unused and thus lack routine care. Severe degradation of BUs in certain core areas, comprising part of the eastern side of Via Roma, has led local authorities to restrict access to extensive public spaces within the oldest core (Fig. 195).

Targeted conservation efforts have nonetheless preserved several traditional structures in very good condition. The most extensive interventions date to the 1990s under the LEADER I and II programmes, which in Osidda supported a "distributed hotel" strategy through the re-use of traditional buildings (Fig. 196). However, current use data indicate that these properties, although repurposed, are generally unused or used intermittently. This reflects an emphasis on tourist supply over the consolidation of everyday services, which fuels the erosion of the resident community and supports abandonment dynamics. Indeed, while several public services have disappeared (e.g., the mini-market, the butcher, the bank, etc.), leaving only traces such as shop signs (Fig. 197). As shown by the use designation map, services cluster around Piazza Bonapace and Piazza dei Caduti still host several services such as the town hall, the post office, a café, and the ethnographic museum; several accommodation facilities are nearby. With the exception of a few contemporary insertions (the reinforced-concrete town hall, a prefabricated timber café pavilion, and the recent granite paving in Piazza Bonapace), the area retains a relationship with the historic nucleus, largely because many services occupy traditional buildings. Additional facilities include the municipal library, also hosted into traditional buildings, a swimming pool and gym, and a care home for older and visually impaired residents, located at the southern edge of the settlement. The social vocation expressed by the healthcare structures aligns with an unimplemented conservation and enhancement strategy (INCANTO) grounded in inclusivity and accessibility and consistent with Italian guidance on small-village regeneration (such as the SNAI), adopting a "design for all"[63] approach to support inclusive, sustainable reactivation, and heritage-led cohesion[64].

Key identity public spaces, such as Piazzetta Delogu, and the covered passageway linking a rear alley to the main square, still exist, although the latter has been enclosed by private appurtenances. Principal axes (Via Roma, Via Mazzini) and several streets retain historic cobbles, albeit modified with cement joints and paired granite slabs to facilitate vehicular passage (Fig. 198). More broadly, the settlement has adapted to the car through the progressive

63 On the topic see for example Ormerod, Newton 2005.

64 Cherchi, Fiorino 2023.

**Fig. 194 (above)**
*Traditional building showing signs of structural failure. Source: author's photo, 2025.*

**Fig. 195 (middle)**
*One of the areas with restrict access within the historic core due to severe degradation of adiacent buildings. Source: author's photo, 2025.*

**Fig. 196 (below)**
*Some of the buildings restored within the LEADER programme within the distributed hotel project. Today, they are not in use. Source: author's photo, 2025.*













**Fig. 197 (above)**
*Cobble pavement in public street showing modern modifications. Source: author's photo, 2025.*




**Fig. 198 (below)**
*An old butcher sign. Source: author's photo, 2025.*

impermeabilisation of surfaces using asphalt and concrete. Moreover, direct observation and community interviews indicate that small and main squares serve only episodically as social spaces; primary squares are frequently used for parking, hosting events (concerts, markets) only occasionally. The emerging picture is markedly car-centred.

The increase in impervious surfaces, changes in paving, the reduction of greenery in the main square, the volumetric growth of the built fabric and the spread of materials such as concrete, together with incongruous roofing (e.g., exposed bituminous membranes and fibre-cement panels), raise concerns about microclimatic behaviour and outdoor thermal comfort. On the basis of the foregoing analyses, particularly the stratigraphic reading, in the next steps multiple scenario models are developed and simulated for both the present configuration and a 1939 reference configuration, permitting like-for-like evaluation of impacts on the settlement's microclimate.

### 5.3.4 From Local GIS Data to the National "*Carta del Rischio*"

"*Carta del Rischio*" is an official GIS-based information system, developed by the History, Drawing, and Conservation Department of Sapienza University of Rome in collaboration with the Italian Central Institute for Restoration (ICR) and the Ministry of Culture (MiC), for cataloging the vulnerability and risk of loss of cultural heritage assets. It integrates georeferenced heritage data (e.g. building locations and conditions) with territorial hazard information to plan and support preventive conservation interventions. The system can overlay the positions of monuments onto maps of seismic or environmental peril, enabling statistical estimation of each asset's exposure and risk of damage. It is used both in normal conditions and during emergencies: under the 2015 MiBACT directive the platform was extended to support post-disaster response (e.g. tracking the recovery of artworks after the 2016 Central Italy earthquake) and to incorporate up-to-date seismic assessment data for protected buildings. Its key objective it's to inform protection strategies, as well as to gather and publish results from research on heritage vulnerability[65].
A specialised module of *Carta del Rischio* is dedicated to historic town centers. In this module, users can delineate and catalog the boundaries and internal composition of each historic centre, using the system as a shared information tool for the Ministry of Culture and local administrations to plan conservation of entire urban districts. The platform supports a multi-scale description of urban fabric: it represents the vulnerability of a historic center across nested levels (from the overall city layout down to individual building façades). To achieve this, data-entry forms have been created, including Urban Units, Building Units, Building Fronts, and Urban Spaces, each capturing relevant characteristics of the historic built environment. These forms are always referred to a Historic Centre form that contains them.
Within the historic-centres workflow, the Urban Space (Spazi Urbani, SU) form was completed to enter public-space data for Osidda into the national database[66]. This was adopted as a pilot for transferring information from the local GIS to the *Carta del Rischio* owing to its the relative of this typology of form. The form is structured into the following sections:

- Localisation and Anagraphic Data: records the reference historic centre and the georeferenced perimeter of the selected space within that boundary; uniquely identifies the space by toponym, and specifies the category (street, square, etc.), intended use, accessibility, and the functions of the facing Urban Units;
- Urban System: describes the plan configuration (e.g., rectilinear, irregular), the nature of the bounding margins, and longitudinal/transverse vertical sections indicating level changes; characterises the fronts of facing Urban Units (e.g., eaves-line type, number of building units, ground-level accesses, residential/non-residential units, total storeys, etc.). This section also inventories elements of the urban space (urban furniture such as flowerbeds and benches; historic street furniture; urban services such as bus stops; lighting systems; elements connecting different levels; and public green areas);
- Dimensional Data: quantifies the scale of the space (width, length, total area, mean carriageway width, and area of green/equipped public space);
- Natural/Artificial System and Transformations: records traditional and modern paving types; the incidence of modern pavements and modern street furniture; types of public planting; the incidence of green and historic green; underground service infrastructures (e.g., water and electricity networks); and a qualitative compatibility rating for lighting systems. These inputs feed the automatically computed Global Index of Transformations, with a date field to enable future comparison. Thematic sub-indices include Modifications and Transformations – Artificial Elements, Modifications and Transformations – Natural Elements, and Presence of Incongruous Lighting Systems;
- Degradation and Structural Instabilities: registers maintenance of green areas; superficial decay on facing fronts; structural/settlement issues in elevation and in plan; and decay affecting pavements, urban furniture, lighting, and level-connection elements. These inputs drive the automatically calculated Vulnerability Index, with sub-indices for urban fronts, in-plane decay, and furniture/lighting;
- Historical Data: collates chronology (scope, event, validity period, century and fraction, dates, motivation, documentation), pre-existences (location, type, and relation to the current space), and sources/bibliography, each recorded item by item;
- Legislation: records legal status and protection measures (type and date of designation), relevant planning instruments (authority, instrument type/indications, and web reference), and compilation metadata (compiler, institution, date);
- Attachments: allows the upload of supporting materials.

65 Fiorani, Cacace 2020.

66 See Attachment 1 for an example of completed form for Osidda. This work was carried out within the framework of the National Interest Project supported by the PNRR, Mission 4, Component 2, Investment 1.1 (Call for Tenders No. 104, published 2 February 2022 by the Italian Ministry of University and Research, MUR), funded by the European Union – Next Generation EU: 2022FABEHA – Vulnerability and risk of historical centres between depopulation, abandonment and extensive re-functionalisation. Materials and tools for the monitoring and management of historical buildings (CUP: F53C24001380006). Grant Assignment Decree No. 18507, 8 October 2024, Italian Ministry of University and Research (MUR). The research was conducted within the University of Cagliari study group led by Principal Investigator Caterina Giannattasio.

## 5.4 The Urban Microclimate Analysis: Modelling and Assessment

### 5.4.1 Urban Models, Meteorological Data Analysis, and Preparation for the Urban Microclimate Simulations

Following step three of the methodology, data assembled through the heritage context analysis were used to construct two digital models for simulation: one representing the current urban morphology (Fig. 199) and another representing the settlement as in 1939[67] (Fig. 200). The QGIS plugin "Geodata to ENVI-met" was employed to export building location, geometry and height; the construction materials assigned to each urban surface and soil; and the location, species, and height of vegetation into ENVI-met[68]. Materials and vegetation used for the current configuration model were:

- Walls:

  Interior lime plaster[69] (2 cm) + bare granite masonry (60 cm)

  Interior cement plaster (2 cm) + granite masonry (60 cm) + exterior cement plaster

  Bare concrete-block wall (20 cm)

  Concrete-block wall (20 cm) + cement plaster (3 cm)

  Glass (2 cm) + brise-soleil (10 cm), for the bar structure in the main square only

- Roofs:

  Sardinian *coppi* clay tiles[70] (10 cm) + lime mortar[71] (2 cm) + reeds (3 cm)

  Tiles (5 cm) + concrete (15 cm)

  Ceramic tiles (5 cm) + concrete (15 cm) — accessible flat roofs

  Bituminous membrane[72] (5 cm) + concrete (15 cm) — inaccessible roofs with exposed waterproofing

  Fibre-cement[73] (30 cm) + concrete (15 cm)

- Natural surfaces:

  Sandy-clay soil

  Grass

- Street pavements:

  Granite cobblestones

  Granite slabs (used both for slab pavements and for short stretches of setts made from the same light-coloured granite)

  Concrete pavement

  Asphalt

  Vegetation (species proxies as per ENVI-met library):

  Hedge (shrubs, oleander and vines)

  Downy oak

  Evergreen broadleaf (generic)

  Holm oak

  Abies alba (silver fir)

  Cypress

  Pine (conifer)

  Populus alba (white poplar)

  Cercis siliquastrum (used as proxy for carob and mimosa, given the shared Fabaceae family)

  Fruit tree (also used for fig and walnut)

  Olea europaea (olive)[74]

Each vegetation type was replicated at three height classes to reflect local variability: small (5–7 m, dependent on the species), medium (10–12 m) and tall (13–15 m).

Materials and vegetation used for the 1939 configuration model were:

- Walls:

  Interior lime plaster (2 cm) + bare granite masonry (60 cm)

- Roofs:

  Sardinian *coppi* clay tiles (10 cm) + lime mortar (2 cm) + reeds (3 cm)

67 This part of the experimentation was carried out with the Department of Civil and Environmental Engineering and Architecture, School of Hydraulic Engineering, University of Cagliari. Research group: Giulia Cherchi, Simone Ferrari, Martina Ferraro, Anastasiya Lisouskaya, Alessandro Santus.

68 ENVI-met version 5.6.1 - Winter23. For the complete database of the used material see Attachment 2.

69 The parameters used to populate the ENVI-met materials database were derived from Calcidrata S.p.A. n.d. a.

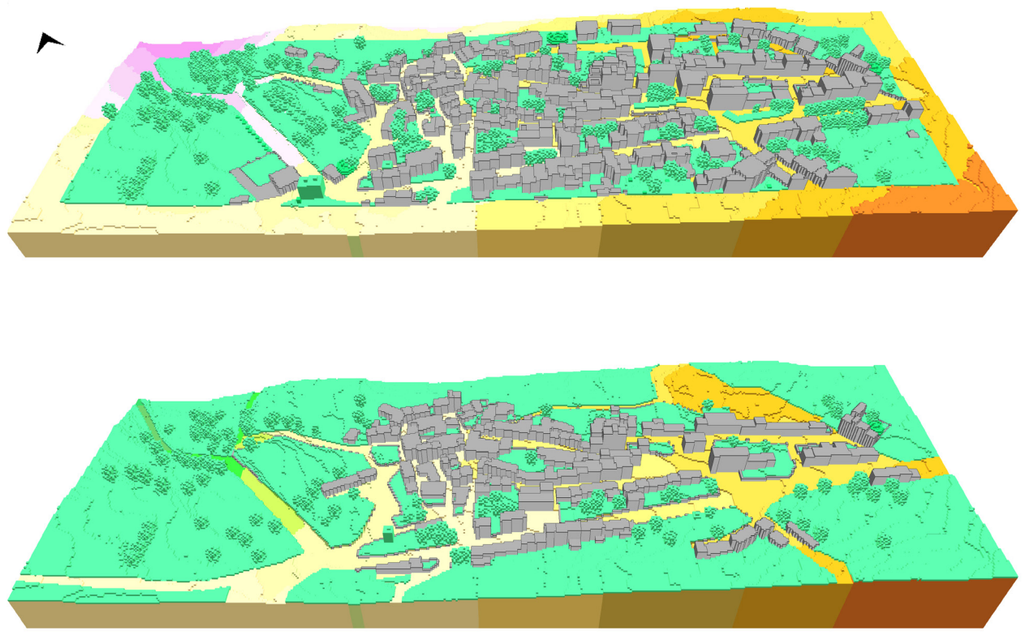
70 The parameters used to populate the ENVI-met materials database were derived from Infobuild n.d.

71 The parameters used to populate the ENVI-met materials database were derived from Mugheddu 2016/2017, p. 101; Calcidrata S.p.A. n.d. b.

72 The parameters used to populate the ENVI-met materials database were derived from Ubakus n.d.

73 The parameters used to populate the ENVI-met materials database were derived from Cornaviera n.d. and other data from "cement" already in the database.

74 Where not further specified materials and vegetation were already present in the ENVI-met database.









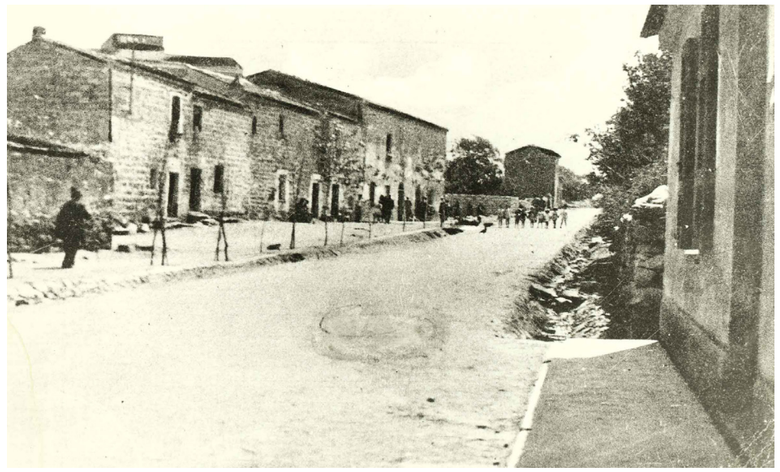


**Fig. 199 (previous page, above)**
*Three-dimensional model of the current urban morphology (buildings are shown in grey and vegetation in green; the level of the underlying terrain topography starts from dark pink, for the lowest elevation, and then ranges, as the level increases, to light pink, light yellow, and orange, indicating the highest elevation). Source: 3D preview ENVI-met Spaces.*

**Fig. 200 (previous page, middle)**
*Three-dimensional model of the 1939 urban morphology (buildings are shown in grey and vegetation in green; the level of the underlying terrain topography starts from dark green, for the lowest elevation, and then ranges, as the level increases, to light green, light yellow, and orange, indicating the highest elevation). Source: 3D preview ENVI-met Spaces.*

**Fig. 201 (previous page, below)**
*Historical orthophoto of the area. Source: Sardinia Geoportal, 1968.*

**Fig. 202**
*Corso Garibaldi, with recently planted trees. Source: Municipal Library of Osidda, 1950s.*

- Natural surfaces:
  Sandy-clay soil
  Grass
- Street pavements:
  Granite cobblestones
  Terre battue (beaten earth)

The same species set was retained for continuity of modelling parameters; however, the trees were repositioned according to the 1968 ortophoto (Fig. 201) (the 1954–55 imagery being too blurred for reliable identification), while trees located within public spaces were removed because historical photographs and community interviews indicate that street and square planting in urban public spaces dates to the 1950s (Fig. 202).
The simulations target past and present summer conditions since, as discussed previously, temperatures in the Mediterranean exhibit a persistent warming trend. The aims are threefold: to assess whether and how changes in urban form, materials, and vegetation have altered the local microclimate; to evaluate the imprint of climate change on Osidda; and to test mitigation options under critical heat conditions (including heat waves), which are becoming more frequent. To verify these conditions, a 2×2 crossed design was implemented, simulating 1939 and 2024 urban morphologies under both past and present climate forcing, yielding four simulations that combine morphology and climate in all permutations.
Meteorological inputs were drawn from the ERA5 hourly reanalysis (1940 - present), produced by the European Centre for Medium-Range Weather Forecasts (ECMRWF)[75]. ERA5 blends observations and numerical weather

75 Hersbach *et al.* 2023; Copernicus Climate Data Store 2025.

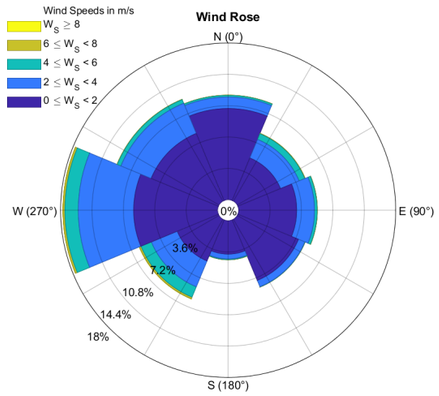



**Fig. 203 (above)**
*Wind rose of wind direction and intensity in summer from the year 2021. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

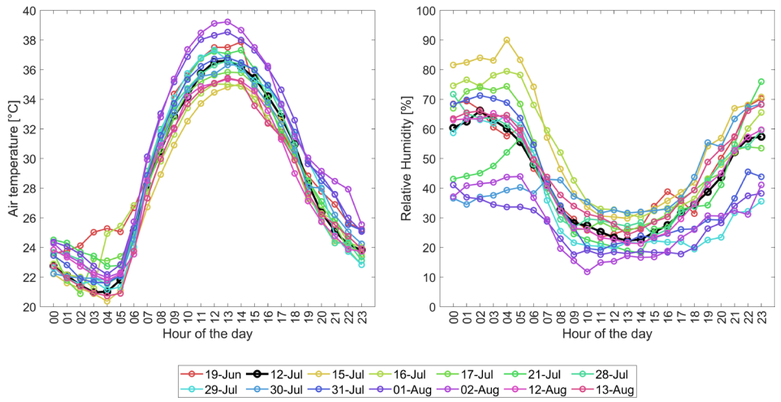



**Fig. 204 (middle)**
*Air temperature (°C) and relative humidity (%) during the critical days in Osidda in 2024 (in black the values for the simulated typical critical day). Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

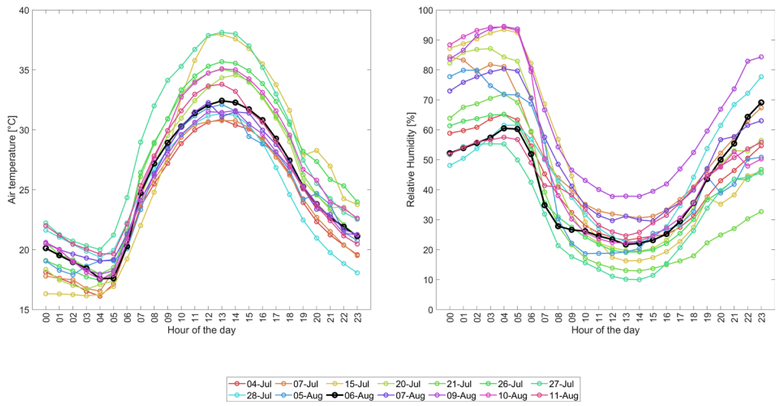



**Fig. 205 (below)**
*Air temperature (°C) and relative humidity (%) during the critical days in Osidda in 1940 (in black the values for the simulated typical critical day). Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*





prediction to provide a spatially and temporally consistent dataset, including near-surface air temperature, dew-point temperature, wind speed and direction, and solar radiation, key parameters required for the simulations. Recent validation studies in Sardinia support the use of ERA5 for regional-scale characterisation against *in situ* measurements[76].

A preliminary analysis of wind direction and speed over the last four summers shows that western direction (~270°) dominate; contributions from other quadrants are minor. Wind speeds are overwhelmingly concentrated in the 0–4 m $s^{-1}$ range (light airs to gentle breezes), occurring chiefly under westerly flow (Fig. 203).

For the present study, a critical day is any day combining tropical nights and hot days, defined as T_min > 20 °C and T_max > 35 °C. The analysis of the critical day trend in Osidda shows a significant upward trend, from only one critical day in 1940 to 14 in 2024. The daily temperature and humidity evolution on these 14 critical days in 2024 highlights a substantial variability. It is relevant to note that the 14 critical days are concentrated in 33 days, meaning that, during this period, almost half of the days are critical ones. The typical critical day should reflect canonical diurnal evolution of air temperature and relative humidity, without anomalies, and should reflect the Osidda summer wind regime (light westerlies).

Under clear-sky conditions, solar radiation should follow a smooth, single-peaked diurnal course (near-zero at night, quasi-cosinusoidal rise after sunrise, a rounded maximum near local solar noon, and a mirror-image decline to sunset). Spurious saw-tooth peaks, non-physical nocturnal values, or maxima far from solar noon indicate incoherence. Relative humidity (RH) should evolve inversely to temperature, typically peaking before dawn, declining to an early-mid afternoon minimum, and rising again in the evening. Days violating these patterns were excluded. Among the 14 critical days, 12 July 2024 was selected as the typical critical day for the current climate (in black, Fig. 204).

For the past climate, ERA5 data from 1940 were used, as they were earliest available year and only one year removed from the morphological reference. Using the same modern-day thresholds returned just one critical day, consistent with lower historical temperatures. To enable like-for-like comparison (14 days), thresholds were proportionally relaxed to T_min > 15.7 °C and T_max > 30.7 °C. From the resulting set, 6 August 1940 was selected as the typical critical day, as it best matched temperature, solar radiation and relative humidity trends without anomalies (in black, Fig. 205).

As a conservative minimum for vertical extent, the model height was set to at least twice the height of the tallest building (Palazzo Delogu, 16 m) plus the local terrain elevation (DTM 27 m), yielding a target of ≥ 86 m for the domain top. The final computational domain is 515 m × 196 m × 91.5 m, centred on the historic core (Fig. 206). A cubic grid with 1 m cell size was

76 Sirigu, Montaldo 2022; Montaldo, Corona 2024.

**Fig. 206 (above)**
*Model area in 2024 configuration. Source: graphic elaboration by Simone Ferrari, Martina Ferraro, and Alessandro Santus.*

**Fig. 207 (below)**
*Model area in 1939 configuration. Source: graphic elaboration by Simone Ferrari, Martina Ferraro, and Alessandro Santus.*




adopted. A vertical telescoping (stretching) of 20% was applied aloft, giving 64 vertical cells (instead of 92) and a total of 6,460,160 cells. The DTM is included, and the domain was rotated 20° counter-clockwise to align with the main street orientation. To minimise boundary effects, we expanded the domain with buffer grid cells on all sides. The buffer width in plan was defined by a 2H rule, with H equal to the maximum building height present in the model. Consequently, the shortest distance between any façade and a lateral boundary was at least 2H. As an illustration, along the upper long side of the plan, where H = 10 m above local ground, the buffer was set to 20 m. In this case, 29 buffer cells were added at each lateral boundary to enhance numerical stability and convergence. A constant wind speed of 1.15 m $s^{-1}$ from 271.5° at 10 m above ground, together with the air temperature and relative humidity of 12 July 2024, were prescribed at the inflow. In ENVI-met, these prescribed inflow values represent the large-scale forcing that governs momentum, heat, and moisture exchanges within the urban canopy; a low, steady wind and a fixed thermodynamic state impose a controlled, reproducible environment for comparing scenarios.
The 1939 morphology was simulated in a domain of 535 m x 216 m x 91.5 m (same maximum building height; same vertical extent). The 1 m cubic grid and 20% vertical telescoping were retained, yielding 7,395,840 cells. The 20° rotation was also maintained for consistency across scenarios (Fig. 207). A constant wind speed of 2.30 m $s^{-1}$ from 273.50° at 10 m above ground, together with the daily average air temperature and relative humidity of 06 August 1940, were prescribed at the inflow.





### 5.4.2 Summer Urban Microclimate Simulations Results

The start time of the simulations of the chosen typical critical days was 5:00, one hour before sunrise in Osidda suring summer, and the simulation comprised 24 hours, ending the following day at 5:00[77].
The simulation results were post-processed using "Biomet", while the model's outputs, spatial maps of the principal microclimatic drivers and of OTC expressed via PMV, were processed with "Leonardo".
The PMV calculation was tested for four categories, representing the most relevant age classes among the inhabitants of Osidda: (a) elderly female (80 years old); (b) elderly male (80 years old); (c) adult female (52 years old, the average female population age); and (d) adult male (45 years old, the average male population age)[78]. All categories shared the same body position (standing), walking speed (1.21 m/s), and summer clothing parameters. The results showed that the first category (elderly females, 80 years old) experienced the highest level of thermal discomfort, and consequently, it was selected as the reference case. This choice is further justified by demographic ageing in small towns[79] and by the settlement's orientation towards small community-based care networks supported by dedicated facilities. Moreover, by prioritising the most vulnerable part of the population, the analysis follows a precautionary principle: if conditions are acceptable for this group, they are expected to be acceptable for the remaining population as well.
Based on the maximum hourly PMV values for the 2024 simulation under

77 The hourly dataset was therefore completed with the first hours of the day following the tyical critical day.
78 ISTAT 2025
79 ISTAT 2024.

**Fig. 208**
*Maximum hourly PMV [-] (where [-] means that the quantity is unitless), at 1.5m above ground, during the simulated day in the four configurations.*
*Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

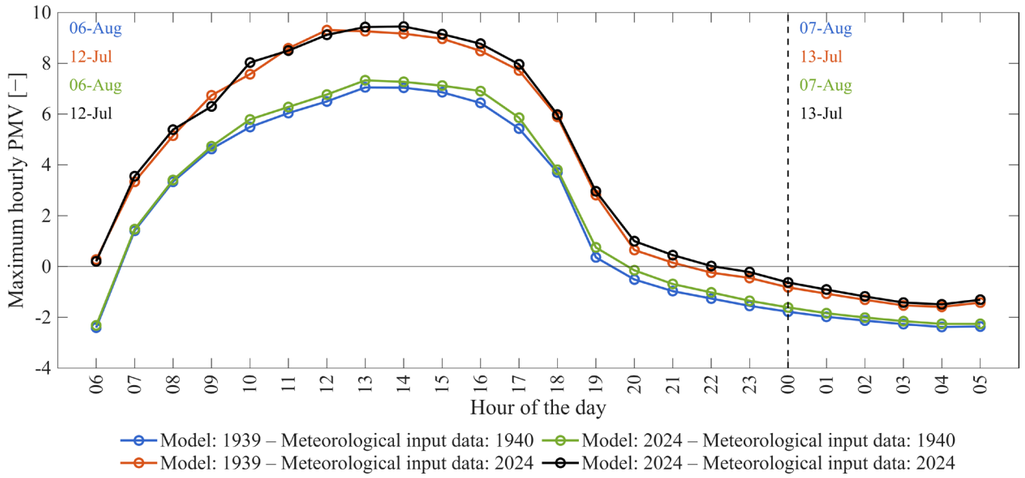


**Fig. 209**
*PMV for four scenarios at 14:00 on 12 July 2024 and 14:00 on 6 August 1940, evaluated at 1.5 m above ground. Grey margins denote buffer cells for numerical convergence. Values follow the reference colour scale (next page); buildings are black, vegetation green. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

current urban morphology (in black, Fig. 208), the daily peak occurs at 14:00; this hour was therefore adopted as the reference (i.e., the most critical) for subsequent analysis. The remaining three configurations (2024 climate with 1939 morphology, 1940 climate with 1939 morphology, and 1940 climate with 2024 morphology) exhibit a closely comparable diurnal pattern, so 14:00 was likewise taken as the common reference hour for the ensuing discussion[80].
In the graph, all configurations fall within the comfort band (−2 to +2) from about 20:00 until early morning. Under the 2024 climate, the +3 threshold is crossed by 07:00 and remains at or above this level until roughly 19:00. Under the 1940 climate, the crossing occurs about an hour later, near 08:00, and values stay above +3 until about 18:00. In short, heat-stress conditions prevail through the sunlit period, with the 2024 climate extending both the duration and the intensity of stress.
The analysis based on the PMV maps at 14:00 at 1.5 m from the ground (i.e., at pedestrian level) representing the different climate and configurations, show clear separation by climate forcing and only modest sensitivity to morphology (Fig. 209). Indeed, all the values under 2024 climate are positive and significantly higher than zero. Therefore, the perception of people frequenting outdoor spaces during the afternoon is one of discomfort due to the extremely hot conditions, resulting in a high degree of physiological stress caused by the heat. Peak values reach 9.45 for the 2024 morphology under 2024 climate (Fig. 209, upper-left) and 9.17 for the 1939 morphology

80 For the complete hourly record see Attachment 3.

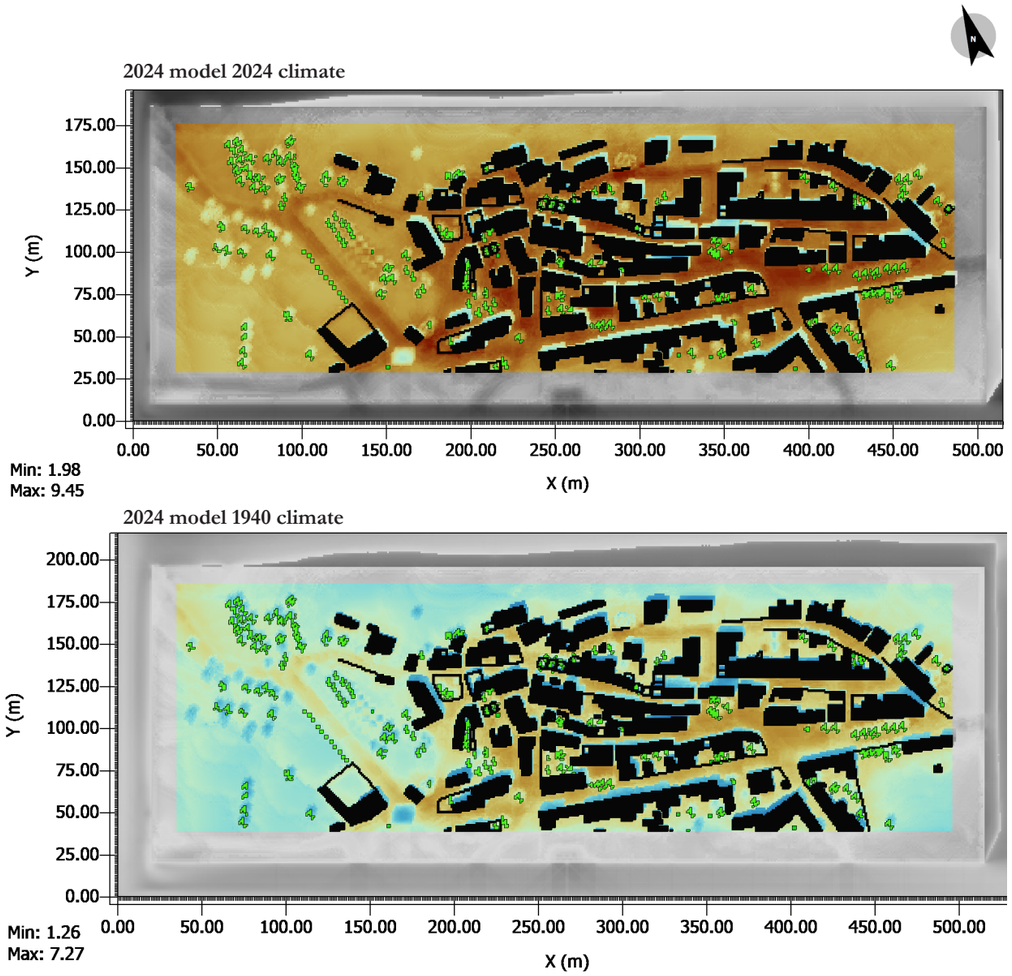
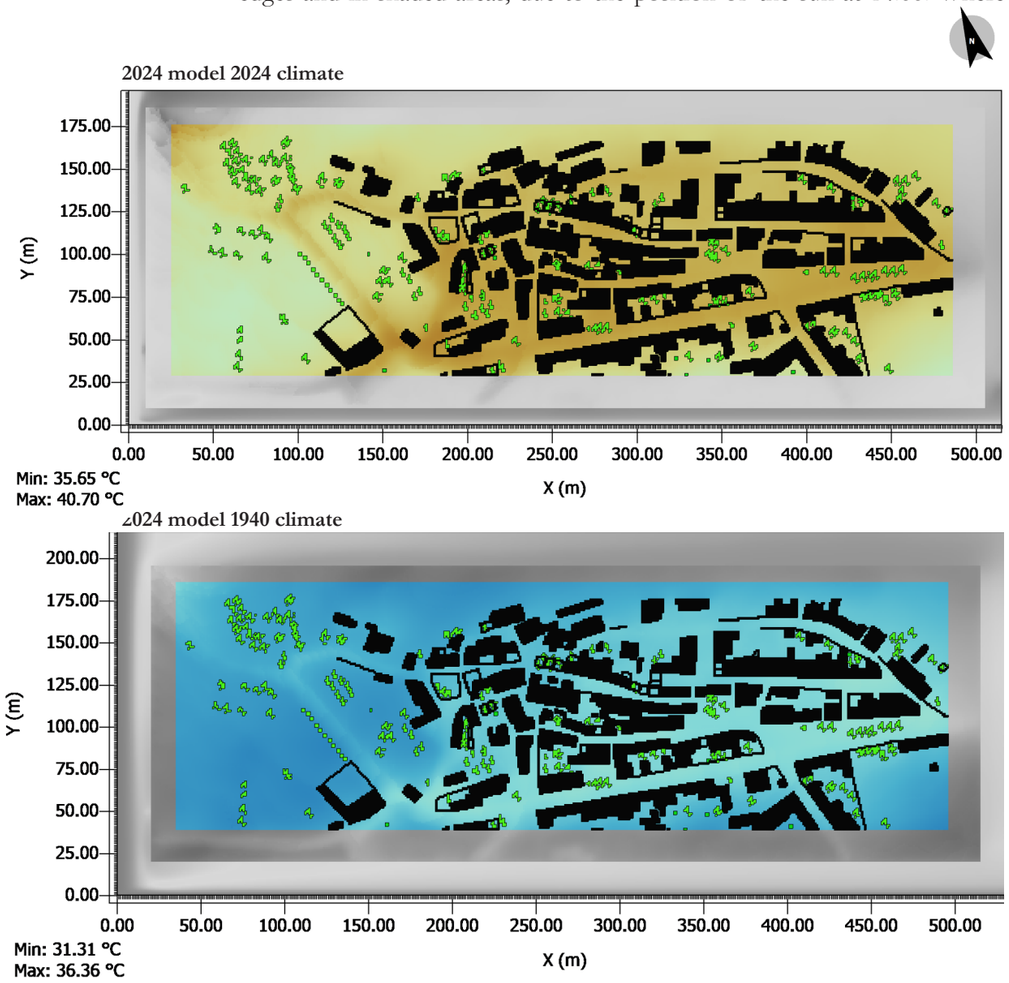
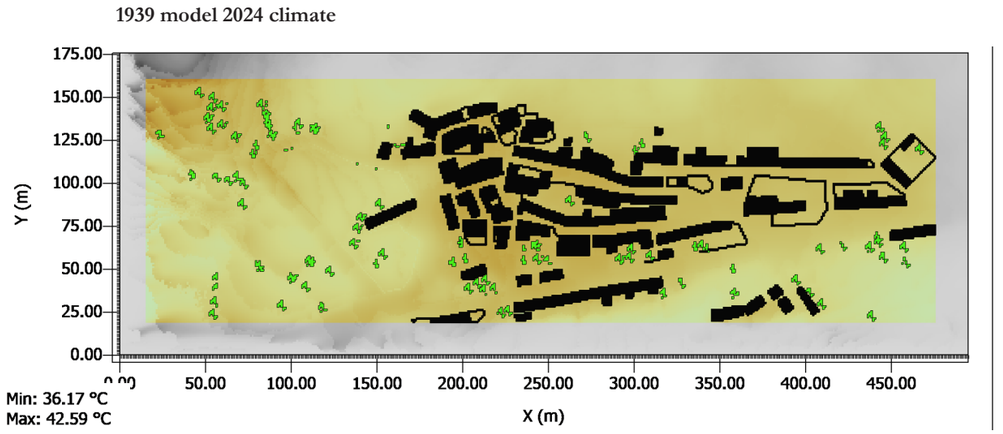


**Fig. 210**
*Air temperature for four scenarios at 14:00 on 12 July 2024 and 14:00 on 6 August 1940, evaluated at 1.5 m above ground. Grey margins denote buffer cells for numerical convergence. Values follow the reference colour scale (next page); buildings are black, vegetation green. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

under the same climate (Fig. 209, upper-right), whereas with 1940 climate the maxima drop markedly to 7.27 (2024 morphology; lower-left) and 7.04 (1939 morphology; lower-right). Thus, the shift from 1940 to 2024 climate increases PMV peaks by roughly +2 units, a change that exceeds the effect of switching morphology at fixed climate, indicating that climate forcing dominates the amplitude of thermal stress. At constant climate, the 1939 configuration yields slightly lower peaks than the 2024 one (9.17 vs 9.45 with 2024 climate; 7.04 vs 7.27 with 1940 climate), but the overall thermal picture changes little, suggesting only marginal mitigation from the urban morphology alone.
Spatially, hotspots concentrate along principal street corridors and exposed squares (open, hard-surfaced areas) under the 2024 climate in both morphologies, while cooler pockets align with vegetated slopes and green edges and in shaded areas, due to the position of the sun at 14:00. Where present, tree cover creates localised "islands" of relief, yet their influence remains highly local relative to the broader thermal field.
The highest values are recorded inside the built area, while moving away from it, the PMV values are lower, with the sole exception of the provincial access road to Osidda, visible on the left and built in asphalt. Thus, during daylight hours, the built environment worsens OTC. In contrast, at night, it contributes to improving thermal perception throughout the village. These results suggest that the compact urban form and construction materials of Osidda provide effective protection from nighttime heat loss. This behaviour is consistent with a traditional design logic oriented toward mitigating cold conditions, which, in the past, were the prevailing climatic stressor in the Northern hilly areas of Sardinia.



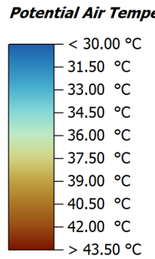



**Fig. 211**
*Reflected solar radiation for four scenarios at 14:00 on 12 July 2024 and 14:00 on 6 August 1940, evaluated at 1.5 m above ground. Grey margins denote buffer cells for numerical convergence. Values follow the reference colour scale (next page); buildings are black, vegetation green. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

Analysing the main drivers of OTC[81] it can be noticed that critical summer days in Osidda are marked by weak ventilation in both periods considered: in all configurations, wind speeds are strongly attenuated within the built fabric, confirming its sheltering role.

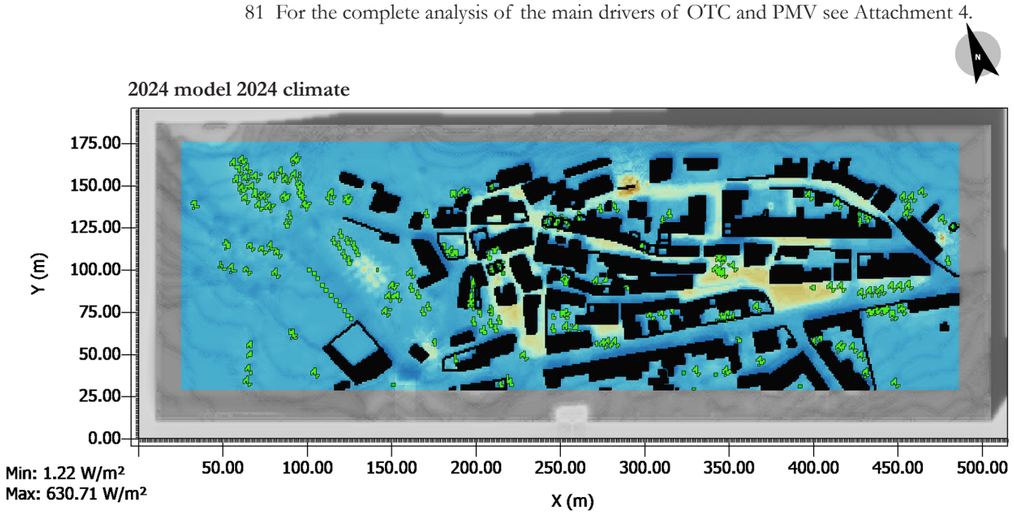
Despite the village's small size, an urban heat island signal is evident, with air temperatures inside the settlement typically 2–4 °C higher than in the surrounding area; the contrast is present in every configuration and is accentuated under the 2024 climate (Fig. 210). Importantly, the hottest air does not coincide with the highest PMV, underscoring that outdoor thermal comfort is multi-factorial and not governed by air temperature alone.

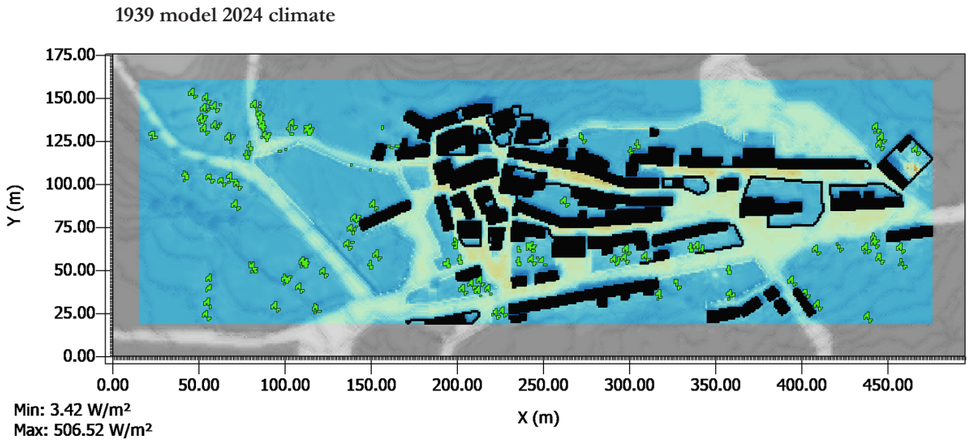
Relative humidity on critical days is low during daylight hours, with much of the settlement registering values more than ten percentage points below the surrounding area; the 1939 morphology tends to retain slightly higher humidity than the 2024 configuration, consistent with greater shading and shelter.

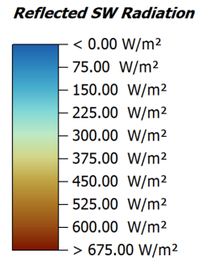
Direct solar radiation is very high across scenarios, as expected for clear summer conditions, except where building mass or tree canopies provide shade; in the 2024 configuration, shading appears more extensive due to increased built volume and additional vegetation in public spaces.

Reflected shortwave is spatially concentrated over light, hard surfaces, particularly façades and light-coloured granite paving in squares, so that combined irradiance (direct + reflected) locally reaches or exceeds 1,360 W $m^{-2}$ (i.e., the energy transported by solar radiation to the ground at noon at the equator), exacerbating thermal stress (Fig. 211). Overall, these patterns

81 For the complete analysis of the main drivers of OTC and PMV see Attachment 4.



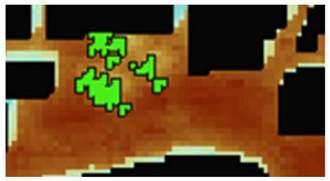



1939 model 2024 climate



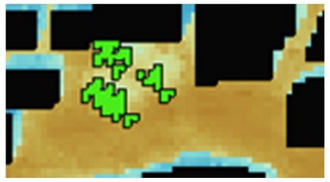
| PMV | 8 |
|---|---|
| T air (°C) | 38,5 |
| RH (%) | 29 |
| Rr (W/m2) | 301 |
| V (m/s) | 0,4 |

2024 model 2024 climate



| PMV | 8,8 |
|---|---|
| T air (°C) | 38,8 |
| RH (%) | 23 |
| Rr (W/m2) | 400 |
| V (m/s) | 0,4 |

2024 model 1940 climate



| PMV | 6,8 |
|---|---|
| T air (°C) | 34,5 |
| RH (%) | 22,5 |
| Rr (W/m2) | 382 |
| V (m/s) | 0,6 |

1939 model 2024 climate



| PMV | 8,3 |
|---|---|
| T air (°C) | 38,3 |
| RH (%) | 30 |
| Rr (W/m2) | 333,5 |
| V (m/s) | 0,4 |

2024 model 2024 climate



| PMV | 8,8 |
|---|---|
| T air (°C) | 39 |
| RH (%) | 23 |
| Rr (W/m2) | 408 |
| V (m/s) | 0,8 |

2024 model 1940 climate



| PMV | 6,9 |
|---|---|
| T air (°C) | 34,5 |
| RH (%) | 22,5 |
| Rr (W/m2) | 400 |
| V (m/s) | 1,3 |

1939 model 2024 climate



| PMV | 8,3 |
|---|---|
| T air (°C) | 38,9 |
| RH (%) | 30 |
| Rr (W/m2) | 320 |
| V (m/s) | 0,1 |

2024 model 2024 climate

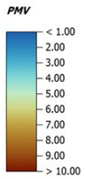


| PMV | 8,2 |
|---|---|
| T air (°C) | 39,2 |
| RH (%) | 24 |
| Rr (W/m2) | 170,6 |
| V (m/s) | 0,7 |

2024 model 1940 climate



| PMV | 6,5 |
|---|---|
| T air (°C) | 34,6 |
| RH (%) | 23,6 |
| Rr (W/m2) | 182 |
| V (m/s) | 0,1 |





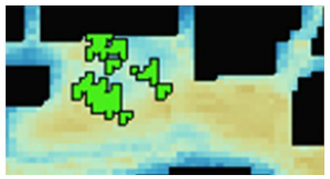



1939 model 2024 climate



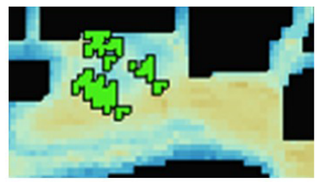
| PMV | 8 |
|---|---|
| T air (°C) | 38,5 |
| RH (%) | 29 |
| Rr (W/m2) | **301** |
| V (m/s) | 0,4 |

2024 model 2024 climate



| PMV | 8,8 |
|---|---|
| T air (°C) | 38,8 |
| RH (%) | 23 |
| Rr (W/m2) | **400** |
| V (m/s) | 0,4 |

2024 model 1940 climate



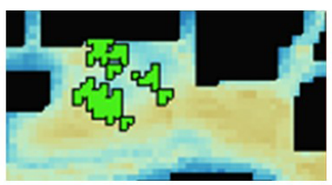
| PMV | 6,8 |
|---|---|
| T air (°C) | 34,5 |
| RH (%) | 22,5 |
| Rr (W/m2) | **382** |
| V (m/s) | 0,6 |

1939 model 2024 climate



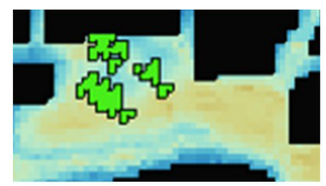
| PMV | 8,3 |
|---|---|
| T air (°C) | 38,3 |
| RH (%) | 30 |
| Rr (W/m2) | **333,5** |
| V (m/s) | 0,4 |

2024 model 2024 climate



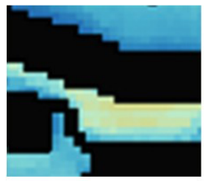
| PMV | 8,8 |
|---|---|
| T air (°C) | 39 |
| RH (%) | 23 |
| Rr (W/m2) | **408** |
| V (m/s) | 0,8 |

2024 model 1940 climate



| PMV | 6,9 |
|---|---|
| T air (°C) | 34,5 |
| RH (%) | 22,5 |
| Rr (W/m2) | **400** |
| V (m/s) | 1,3 |

1939 model 2024 climate



| PMV | 8,3 |
|---|---|
| T air (°C) | 38,9 |
| RH (%) | 30 |
| Rr (W/m2) | **320** |
| V (m/s) | 0,1 |

2024 model 2024 climate



| PMV | 8,2 |
|---|---|
| T air (°C) | 39,2 |
| RH (%) | 24 |
| Rr (W/m2) | **170,6** |
| V (m/s) | 0,7 |

2024 model 1940 climate



| PMV | 6,5 |
|---|---|
| T air (°C) | 34,6 |
| RH (%) | 23,6 |
| Rr (W/m2) | **182** |
| V (m/s) | 0,1 |

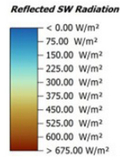



**Fig. 212**
*PMV values (previous page) and reflected radiation values in zoom areas: Piazza Bonapace (first row), Piazza dei Caduti (second row), and Via Roma (third row). Source: graphic elaboration by Giulia Cherchi, Simone Ferrari, and Alessandro Santus.*

indicate that solar radiation is the dominant driver of PMV, as well as the impact of climate change over 85 years of difference between simulated climates.
To corroborate the settlement-scale findings, targeted zooms were produced for three representative areas in order to quantify how PMV and its principal driver, reflected short-wave radiation, vary under different climates and morphologies. The chosen areas were two squares (Piazza Bonapace and Piazza dei Caduti) and one narrow street (Via Roma), to see how different urban spaces work in terms of OTC in the different combinations (Fig. 212).
The primacy of climate forcing is confirmed by the comparison between the central panel (2024 model, 2024 climate) and the right panel (2024 model, 1940 climate), which differ by roughly two PMV units. Although the left panel (1939 model, 2024 climate) and the central panel are closer, sligh differences are still present in the two squares exhibiting morphological and material changes, for example a more reflective granite paving replacing beaten earth, which are partly counterbalanced by vegetation newly introduced in the contemporary setting.
Along Via Roma, PMV in the current configuration (central panel) remains high despite only moderate reflected radiation, consistent with radiative trapping within a confined canyon. In the narrow-street zoom, the 1939 morphology appears to perform less well than the current case: although PMV is similar, winds are more strongly attenuated and reflected short-wave radiation is higher. Likely contributors include differences in façade or paving albedo, and volume increases that rise throughflow.
Overall, reflected radiation dominates comfort in open paved areas, whereas street-canyon follow different dynamics, being the PMV more independent from surface brightness.

### 5.4.3 Supplementary Experimental Analysis

The analyses outlined above raised a set of questions that were pursued through supplementary experimental investigations. First, the wintertime functioning of the settlement in the past was examined to test whether urban morphology and material choices were historically aligned with resource efficiency by limiting heat losses during harsher winters, and to clarify how these attributes relate to the observed local heat-island behaviour. Second, the effects of recent works in the main square, Piazza Bonapace, were investigated, as the space was the object of a recent modification. In 2024 models this space coincide with distinct hotspots in the PMV and with notably higher reflected short-wave radiation, prompting a counterfactual enquiry into how PMV would have changed if intervention hadn't occurred, particularly if the original green elements had been retained. Third, the influence of façade surface characteristics on the urban microclimate was assessed, with attention to finish types that compare bare masonry with plastered walls, while also considering the contemporary tendency to strip finishes and expose the underlying fabric.





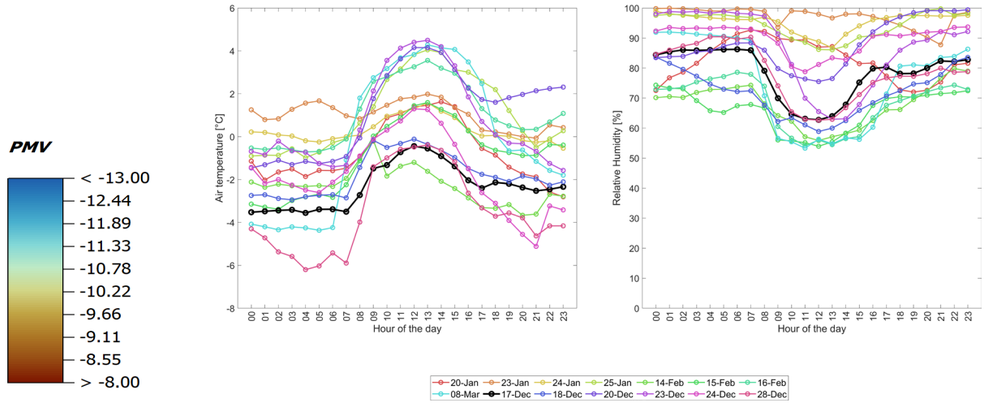
*1940 Winter Simulation*
To test the hypothesis that the historical settlement performed favourably in winter by conserving heat under a harsher climate, a simulation was run with the 1939 morphology forced by winter 1940 meteorology. The dataset was screened to select 14 representative days satisfying the following criteria: nocturnal minimum temperature T_min < 0 °C and daytime maximum temperature T_max < 5 °C, together with internally consistent nocturnal and diurnal short-wave radiation conditions. Using the same criteria as the summer simulations, 17 December 1940 was chosen as the winter typical critical day to be simulated (in black, Fig. 213).
The 1939 morphology was simulated in a domain of 495 m x 176 m x 91,5 m (same maximum building height; same vertical extent as the summer simulations). The 1 m cubic grid and 20% vertical telescoping were retained, yielding 5,575,680 cells. The 20° rotation was also maintained. A constant wind speed of 4.00 m $s^{-1}$ from 1.63° at 10 m above ground, together with the daily average air temperature and relative humidity of 17 December 1940, were prescribed at the inflow.
The day is markedly cold: PMV remains negative at all hours, with a minimum of −13.63 at 07:00 and a least-adverse value of −8.32 at 12:00, indicating persistent cold discomfort across the period considered (Figs. 214, 215).
Between 11:00 and 14:00 conditions are comparatively better, consistent with the onset of direct solar gains on sunlit streets and squares; non-shaded segments systematically exhibit less negative PMV than shaded ones, while zones with strong reflected short-wave also show modest relief.
Wind can be a counteracting driver: where speeds rise, especially in open exposures, PMV becomes more negative even during daylight. Conversely, within the compact built core, wind speeds are generally suppressed, and PMV improves relative to the surroundings, underscoring the sheltering benefit of the dense fabric (Fig. 216).
At night, once solar and reflected components vanish, the spatial pattern of comfort tracks wind shielding more directly, with narrow streets reading less negative PMV than open areas: a difference on the order of two PMV units between sheltered canyons and exposed sites is observable in the night frames.

**Fig. 213 (p. 256, above)**
*Air temperature (°C) and relative humidity (%) during the winter critical days in Osidda in 1940 (in black the values for the simulated typical winter critical day). Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

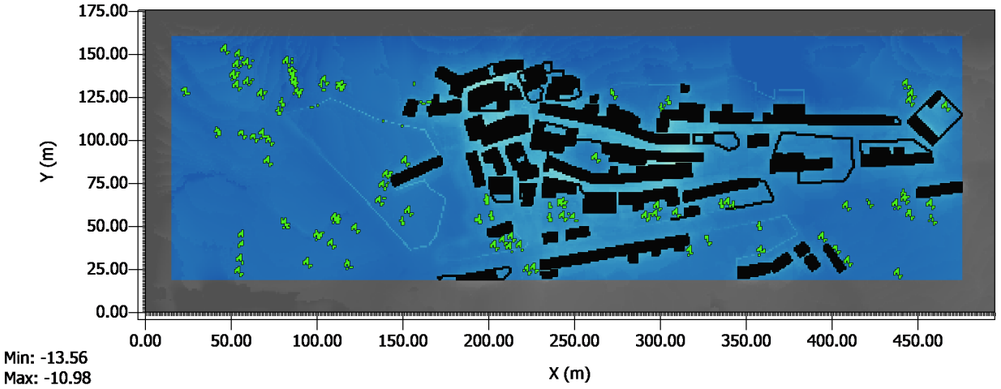
**Fig. 214 (p. 256, below)**
*PMV at 6:00 ad 8:00 on 6 August 1940, at 1.5 m above ground. Grey margins denote buffer cells. Values follow the reference colour scale; buildings are black, vegetation green. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

**Fig. 215 (p. 257, above)**
*Maximum hourly PMV[-] (where [-] means that the quantity is unitless), at 1.5m above ground, during the simulated day in winter 1940. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

**Fig. 216 (p. 257, below)**
*Wind speed at 6:00 ad 8:00 on 6 August 1940, at 1.5 m above ground. Grey margins denote buffer cells. Values follow the reference colour scale; buildings are black, vegetation green. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

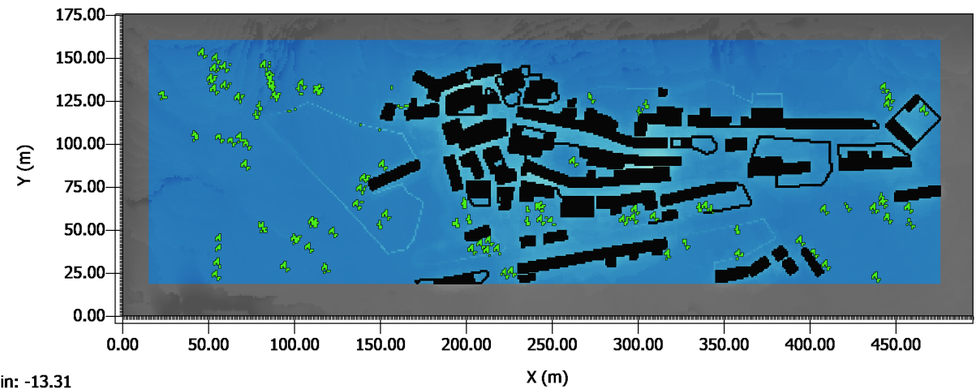



6:00




Min: -13.56
Max: -10.98

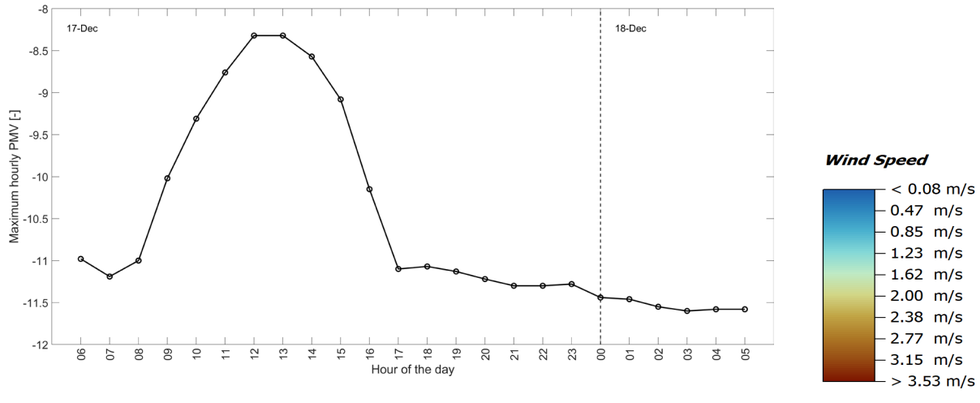
8:00



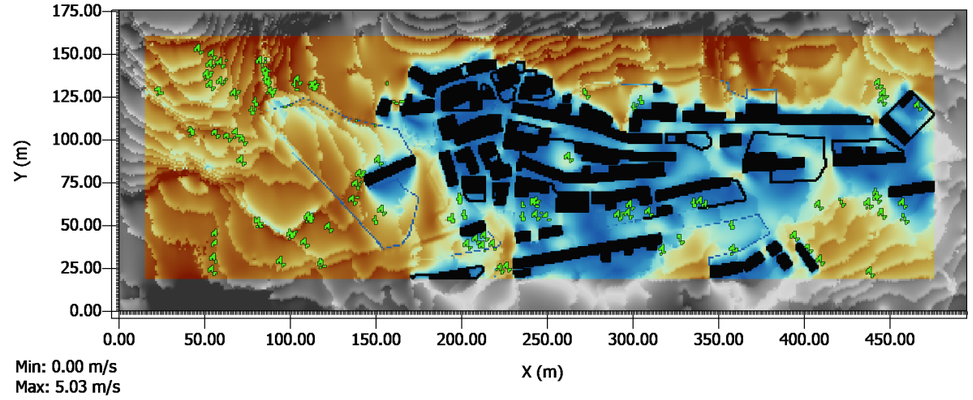

Min: -13.31
Max: -11.00





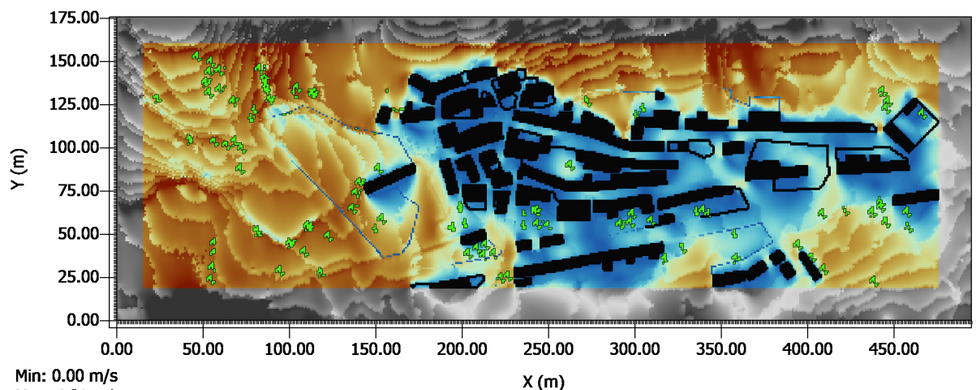



6:00




Min: 0.00 m/s
Max: 5.03 m/s

8:00




Min: 0.00 m/s
Max: 4.91 m/s

*Piazza Bonapace Vegetation Loss Impacts*

Using the same PMV scale, the past (Fig. 217) and the current (Fig. 218) configrations of Piazza Bonapace are compared (Fig. 219). The figure representing the current situation shows a broad, contiguous hotspot over the square, consistent with limited shading. In the past variant, the hotspot footprint contracts and fragments into smaller areas, with cooler patches appearing within the square and along its margins, consistent with added shade and cooler zones induced by vegetated elements.



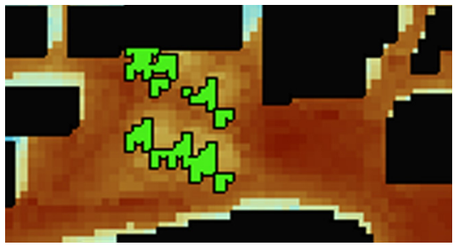
**Fig. 217 (above)**
*Piazza Bonapace before the renovation. Source: Google Maps, 2011.*



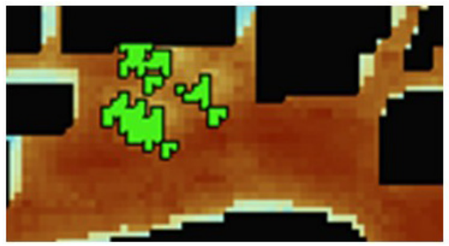
**Fig. 218 (middle)**
*Piazza Bonapace after the renovation. Source: author's photo, 2025.*

**Fig. 219 (below)**
*PMV for the past and the current configurations of Piazza Bonapace at 14:00 on 12 July 2024, evaluated at 1.5 m above ground. Source: graphic elaboration by Giulia Cherchi, Simone Ferrari, and Alessandro Santus.*

**Past configuration, 2024 climate**




**Current configuration, 2024 climate**








*Plaster parametric simulations*

To assess the influence of façade surfaces on the urban microclimate, a detailed ENVI-met model was constructed for a representative segment of Via Mazzini comprising a straight street flanked by buildings on both sides, thereby reproducing the radiative exchange typical of urban canyons (Figs. 220, 221). The model was deliberately built without a digital terrain model since the focus is on local street-canyon processes. A parametric approach was adopted in which the sole variable is the façade surface condition; all



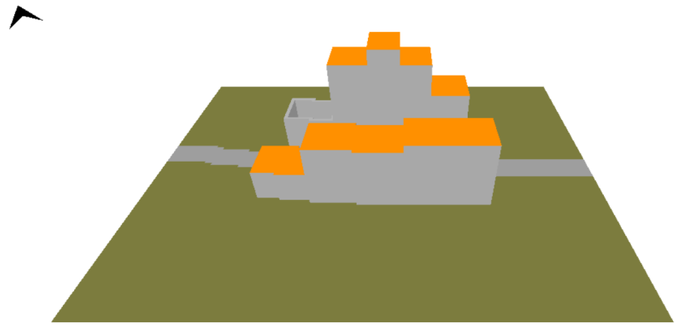
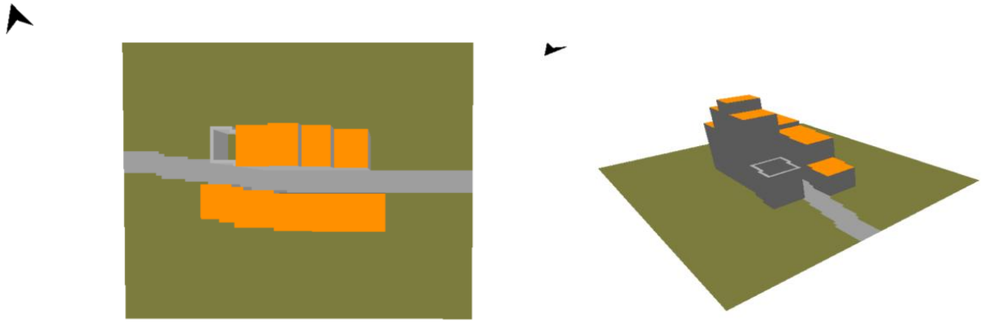



**Fig. 220 (above)**
*Localisation of the modelled buildings in Osidda, Via Mazzini. Source: graphic elaboration by Anastasiya Lisouskaya.*

**Fig. 221 (below)**
*Model for the plasters parametric simulations. Source: graphic elaboration by Anastasiya Lisouskaya.*



other boundary and forcing conditions remain fixed. The tested façade materials are bare granite, lime plaster, cement plaster, and a high-reflectance coating applied over lime plaster and over cement plaster. The computational domain, measures 60 m x 50 m x 32 m, with a uniform cell size of 0.5 m. The model is georeferenced to Osidda and oriented 18 degrees clockwise from grid north.
The material used in the model[82] were:

- Walls:

  Configuration 1: bare granite walls (60 cm)

  Configuration 2: granite walls (60 cm) + lime plaster (3 cm)

  Configuration 3: granite walls (60 cm) + cement plaster (3 cm)

  Configuration 4: granite walls (60 cm)+ lime plaster (3 cm) + reflective coating (0,34 mm)

  Configuration 5: granite walls (60 cm) + cement plaster (3 cm) + reflective coating (0,34 mm)

- Roofs:

  Tiles (5 cm) + lime mortar (2 cm) + reeds (3 cm). This reflects the prevailing configuration following renovations under the LEADER programme, which generally adopted traditional techniques while replacing the original coppi with newer clay tiles. One building is a ruin and therefore has no roof.

- Natural surface:

  Sandy-clay soil

- Street pavement:

  Granite cobblestones

Alongside the materials commonly present in historic centres, such as lime and cement plasters, a reflective coating was included to test the effect of high-albedo technology on the outdoor urban microclimate. The choice was made to test the prevailing evidence that highly reflective finishes, while potentially improving indoor performance, may adversely affect external microclimatic conditions due to their high solar reflectance and low absorptance.

Reflective coating properties were sourced from manufacturers' technical documentation: solar reflectance, absorptance, and emissivity from the thermophysical properties of SUPER THERM coating, and specific heat capacity, thermal conductivity, density, and thickness from the Report to Superior Products International II, Inc[83].

Each configuration was simulated on 12 June 2024 for a 12-hour period from 05:00 to 17:00. Outputs for comparison were extracted at 14:00, identified as the critical hour with the highest PMV, at 1.5 m above ground level. PMV was

82 For the complete characteristics of used materials see Attachment 2.

83 For the complete technical sheets see Attachment 5.





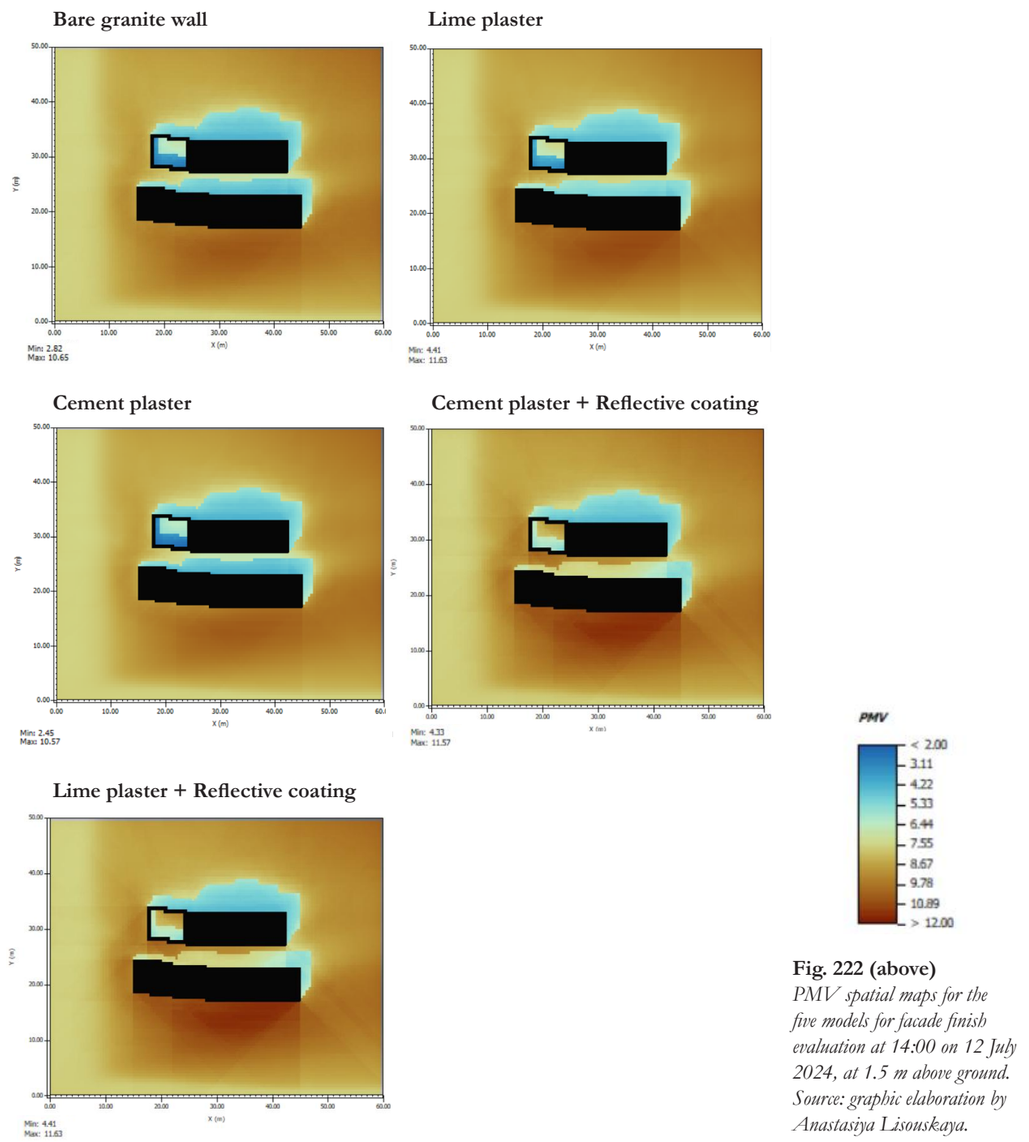



**Fig. 222 (above)**
*PMV spatial maps for the five models for facade finish evaluation at 14:00 on 12 July 2024, at 1.5 m above ground. Source: graphic elaboration by Anastasiya Lisouskaya.*

| | Bare Granite | Lime Plaster | Cement Plaster | Reflective Material with Lime Plaster Base | Reflective Material with Cement Plaster Base |
|---|---|---|---|---|---|
| **Min** | 2.82 [-] | 3.15 [-] | **2.45** [-] | 4.41 [-] | 4.33 [-] |
| **Max** | 10.65 [-] | 11.01 [-] | **10.57** [-] | 11.63 [-] | 11.57 [-] |

**Fig. 223 (below)**
*Table. PMV values for the five models for facade finish evaluation at 14:00 on 12 July 2024, at 1.5 m above ground. Source: graphic elaboration by Anastasiya Lisouskaya.*




| Bare Granite | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 2.90 | 4.45 | 6.05 | 7.40 | 9.41 | 10.45 | 10.71 | 10.65 | 10.24 | 9.43 | 8.32 |

| Lime Plaster | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 3.05 | 4.88 | 6.56 | 7.97 | 9.46 | 10.47 | 10.95 | 11.01 | 10.71 | 10.20 | 9.03 |

| Cement Plaster | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 2.90 | 4.44 | 5.96 | 7.35 | 9.41 | 10.44 | 10.59 | 10.57 | 10.19 | 9.36 | 8.37 |

**Fig. 224 (above)**
*Graph. Hourly max PMV comparison graph for the five models.*
*Source: graphic elaboration by Anastasiya Lisouskaya.*

| Reflective Material + Lime Base | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 3.81 | 5.53 | 6.91 | 8.30 | 9.76 | 10.95 | 11.54 | 11.63 | 11.27 | 10.59 | 9.30 |

| Reflective Material + Cement Base | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day [h] | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 3.80 | 5.51 | 6.88 | 8.24 | 9.67 | 10.92 | 11.48 | 11.57 | 11.13 | 10.47 | 9.22 |

**Fig. 225 (below)**
*Tables. Hourly max PMV values for the five models.*
*Source: graphic elaboration by Anastasiya Lisouskaya.*





calculated for the 80-year-old female profile, as in the preceding analyses[84].

The comparative analysis indicates that the reflective coating yields the highest PMV, whereas the cement-plaster configuration produces lower potential air temperature and the lowest PMV, suggesting a more favourable outdoor thermal environment (Figs. 222, 223, 224, 225). These findings, however, address only the external microclimate. Moreover, it should be noticed that the difference between bare wall, lime plaster, and cement plaster in terms of performance is minimal.

From a conservation standpoint, cement plaster is generally incompatible with historic substrates, despite its outdoor microclimate advantage. Beyond the influence on urban microclimate, other criteria such as visual compatibility should be considered. For example, the bright-white appearance of many commercial reflective coatings (Fig. 226) would typically preclude their use on historic façades for visual reasons. Moreover, most of them are not phisically and chemically compatible with historic materials. Although a small number of studies have explored reflective formulations designed for heritage compatibility, both materially and aesthetically, the evidence base remains limited[85].

Material choice in heritage contexts should therefore follow a multi-criteria assessment that weighs microclimate outcomes alongside substrate compatibility, reversibility, durability, and visual appropriateness.

Expanded research on heritage-compatible reflective finishes, together with integrated simulations and monitoring of indoor–outdoor interactions, is needed to support robust decision-making.

84 For the complete analysis see Attachment 5.

85 e.g. Becherini *et al.* 2018.

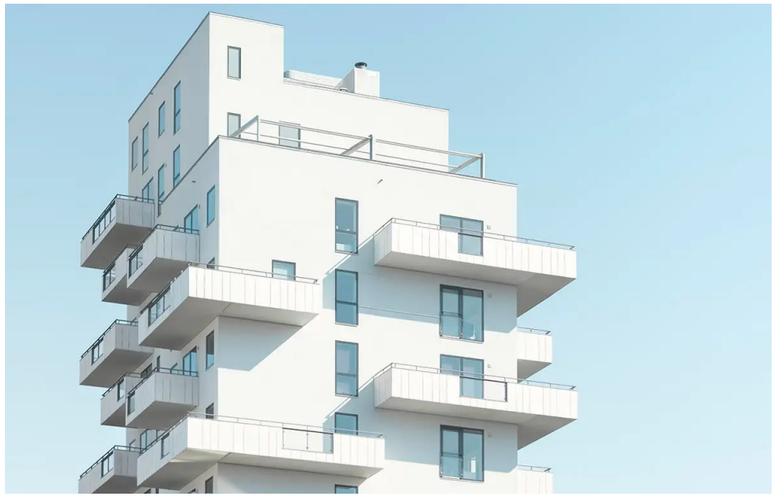


**Fig. 226**
*Example of a reflective coating on a modern building.*
*Source: images.newscientist.com.*

## 5.5 The Design Phase: One Possible Operative Application of the Study

The combined analysis of the heritage context and the summer microclimate, which anticipates the increasingly frequent conditions expected across Mediterranean settings, indicates that urban squares warrant priority attention. They are the most exposed open spaces, they offer the greatest scope for targeted interventions, and they hold significant latent potential. The proposed design is conceived to complement ongoing initiatives in the area, such as the project INCANTO's work on inclusivity and accessibility, by enhancing the liveability of public open spaces for all users and by encouraging the creation of interpretive routes that valorise the historic centre.

Three squares were selected as focus areas for testing mitigation strategies: Piazzetta Delogu, Piazza Bonapace, and Piazza dei Caduti. Although these spaces are not consistently central to everyday sociability, they host a range of services and maintain strong spatial and symbolic ties with the historic fabric[86]. The choice and design of interventions in these sites are guided by architectural

86 Piazzetta Delogu is currently used only marginally, while Piazza Bonapace is predominantly uses as a parking. Piazza dei Caduti is the most actively used space, largely due to the presence of services; nevertheless, it retains further potential as a focal point of everyday social life.

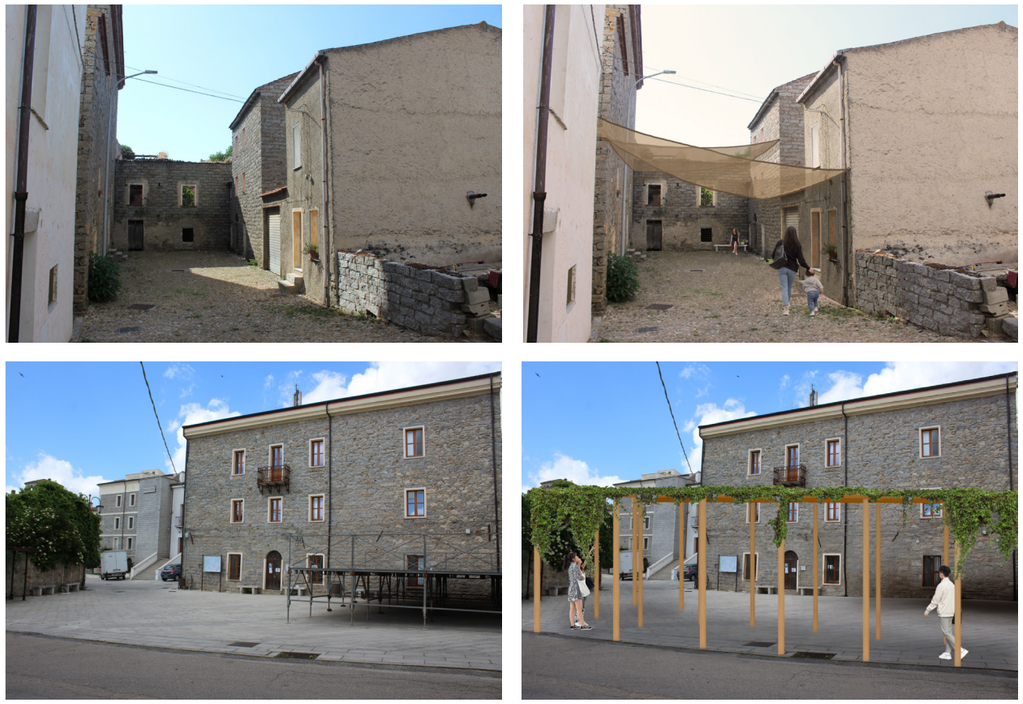


**Fig. 227**
*Simulation of the designed mitigation solutions. In the first row sun sails in Piazzetta Delogu, in the second row an example of green pergola in Piazza dei Caduti. Source: author's graphic elaboration.*





and microclimatic factors, together with installation and maintenance costs. Given that most of the surrounding buildings are part of the historic stock, geometric alterations to built form have not been considered appropriate at this stage, in order to uphold conservation principles and avoid undue risk.

Microclimatic assessment shows that, in summer conditions, wind is not the principal driver of thermal discomfort. Rather, direct and reflected short-wave solar radiation is the dominant determinant of the PMV. Shading therefore emerges as the primary strategy, since it attenuates both direct and reflected components. As elevated humidity is not a critical issue in the study area, carefully designed greening and evaporative cooling measures are also judged suitable and potentially effective.

The final mitigation package (Fig. 227) comprises geometric shading with tensile sun sails in Piazzetta Delogu, designed to be retractable or demountable overnight and during the winter season, and vegetative shading via green pergolas in Piazza Bonapace and Piazza dei Caduti, coupled with evaporative cooling delivered through fine-mist spray nozzles. Deciduous climbers were selected for the pergolas to admit winter sunlight, in keeping with Mediterranean practice.

Each proposed intervention was implemented and parameterised in the ENVI-met digital model of summer 2024 with 2024 morphology. The sun sails installed above the pedestrian area in Piazzetta Delogu were modelled as a suspended building element, with assigned values (i.e., absorption, transmission, reflection, emissivity, specific heat, thermal conductivity, density) derived from experimental data reported by Zhao *et al.* (2024) (Fig. 228). The element was designed to extend from the nearest lane (Via Mazzini) to guide the visitor towards the square. At the same time, the shape followed the perimeter of the bordering buildings, with 1 m of distance from them to avoid interactions with the historical surfaces and to allow ventilation. The result was a light impermeable structure, composed of two adjacent parts positioned at different elevations to adapt to the variation of roof heights of

Parameters of the shading materials and mist-spray systems.

| Parameters | Sun sail | Parameters | Mist-spray system |
|---|---|---|---|
| The validation experiment (on-site and in simulation) | | | |
| Texture | Polyethylene | Arrangement | Parallel |
| Thickness (m) | 0.003 | Water flow (g/s) | 2 |
| Density (kg/m$^3$) | 840 | Layout height (m) | 2 |
| Absorption | 0.75 | Spacing between nozzles (m) | 1 |
| Transmission | 0.15 | Number of nozzles | 6 |
| Reflection | 0.1 | Water density (g/cm$^3$) | 1 |
| Emissivity | 0.9 | Mist particle diameter (μm) | 5 |
| Specific heat (J/(kg·K)) | 2817 | | |

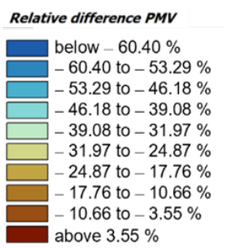
**Fig. 228**
*Parameters of the shading materials and mist-spray used for the modelling and simulation of the mitigation solutions. Source: Zhao et al. 2024, p. 6.*

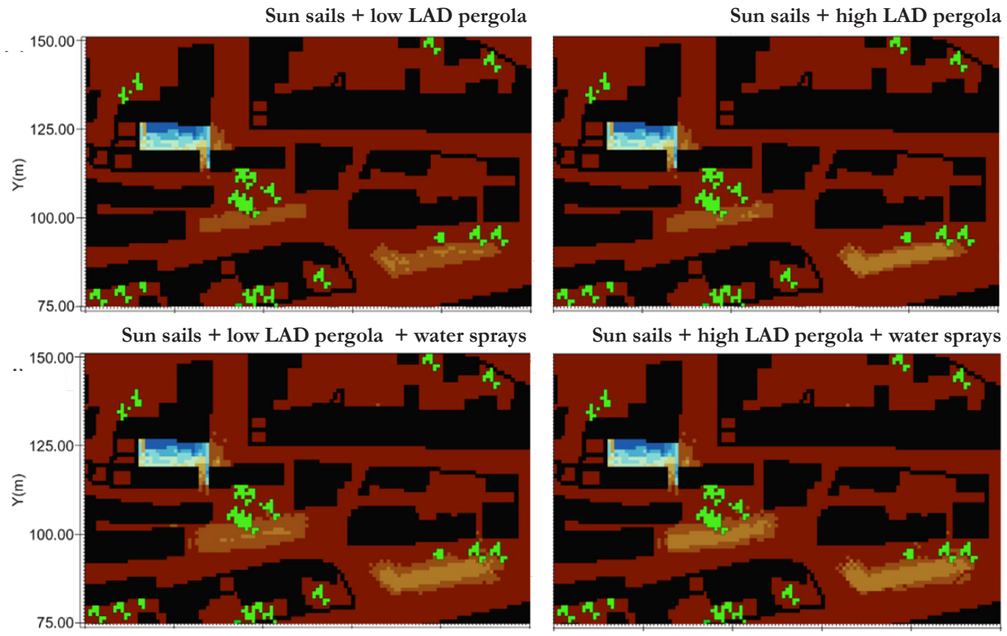
**Fig. 229 (p. 266)**
*The percentage difference in PMV between the current scenario and the scenario with the proposed intervention. Each quantity are represented in colours according to the colorbar, the buildings in black, and the vegetation in green. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

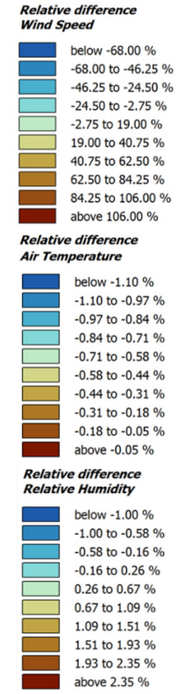
**Fig. 230 (p. 267)**
*The percentage difference in wind speed, air temperature, and relative humidity between the current scenario and the scenario with the proposed intervention. Each quantity are represented in colours according to the colorbar, the buildings in black, and the vegetation in green. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

**Fig. 231 (p. 267, below, right)**
*Mitigation interventions location within the historic centre. Source: author's graphic elaboration.*

the buildings constituting the limits of the square.
In Piazza Bonapace and Piazza dei Caduti, shading was implemented through green-covered pergolas in two configurations: with and without water spray systems. Moreover, to assess the impact of vegetation density on microclimate, different leaf area density (LAD) values, i.e., the one-sided leaf surface area per unit volume of canopy ($m^2/m^3$), were assigned to the plants covering the pergolas. The two values used (0.15 $m^2/m^3$ and 0.5 $m^2/m^3$) represented, respectively, the foliage density expected shortly after installation and after several years of growth. This enabled an evaluation of whether it is preferable to invest from the outset in more expensive but mature vegetation, rather than in younger plants.
Both pergolas had a height of 3.5 m and simple geometrical configurations. The one in Bonapace Square was a 30 m-long, 4 m-wide rectangle with a covered area of 120 $m^2$, designed to cover an area already arranged as a sitting area. The one in Piazza dei Caduti was L-shaped, with a long side of 30 m, a short side of 7 m, and a width of 4 m, with a covered area of around 150 $m^2$. Such a configuration was thought to serve as a separation between Corso Garibaldi, a fast-moving road, and the square, enabling pedestrians to feel safer. Moreover, the L-shape was intendend to guide the visitors towards the historic core of the village.
The water spray system was modelled using point sources representing water nozzles, with each source positioned at 2.5 m above the ground level. This value was selected based on findings by Zhao *et al.* (2024), who identified 2.3 m as the optimal spray height for cooling pedestrians at 1.5 m, but it was slightly adjusted to 2.5 m to align with the model's vertical mesh resolution. The sources were arranged in linear rows, with a spacing of 1 m between adjacent sources and 2 m between the two rows. A total of 60 sources were installed beneath the pergola in Piazza Bonapace, while 79 were placed under the pergola in Piazza dei Caduti. Each source operated at a flow rate of 2 g/s, resulting in a total water demand of approximately 1 $m^3/h$. This raised practical concerns about resource consumption, particularly in a region like Sardinia, which frequently faces drought conditions. This consideration motivated the decision to run the simulations also without the evaporative cooling system, to weigh the comfort benefits against water consumption and to identify the most sustainable configuration. A dedicated simulation was conducted for each of the proposed configurations, all keeping the sun sails in Piazzetta Delogu, resulting in a total of four simulations.
To evaluate the effectiveness of the selected mitigation strategies, the percentage difference in PMV between the current scenario and each proposed intervention was assessed (Fig. 229). Since the sun sails' features in Piazzetta Delogu remain constant, its outcomes are identical across all scenarios: a consistent PMV reduction of over 50%, reaching peaks of more than 60%. This confirms its high effectiveness in this context.
In Piazza Bonapace and Piazza dei Caduti, the basic pergola setup (low LAD, no sprays) already achieves some thermal comfort improvements (with PMV reductions of up to 10.66% and 17.76%, respectively). Still, their effectiveness is lower than that of the sun sails. Increasing the LAD enhances performance, especially in Piazza dei Caduti, where PMV reductions reach levels previously



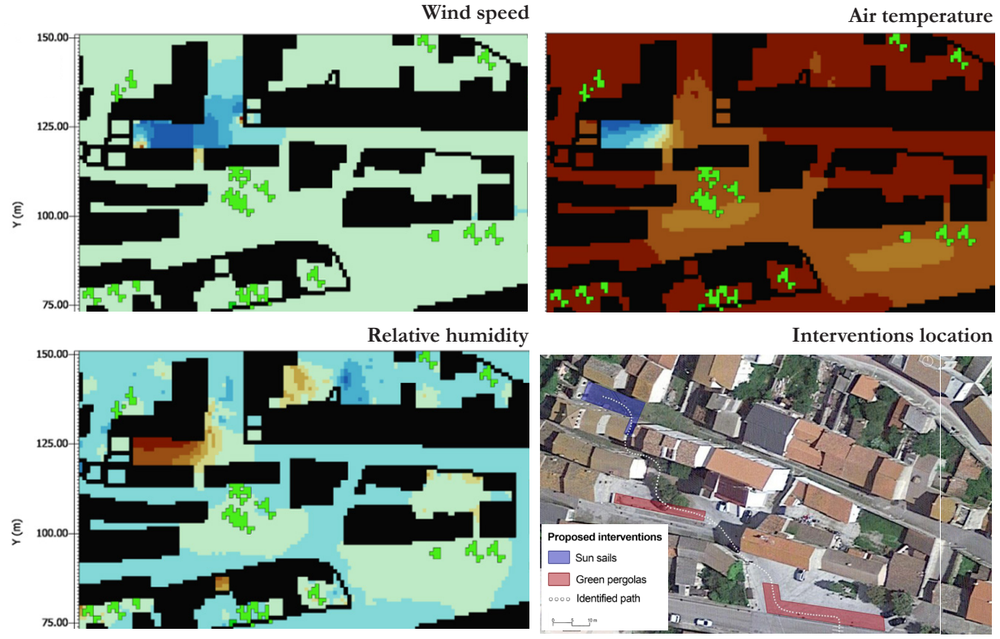
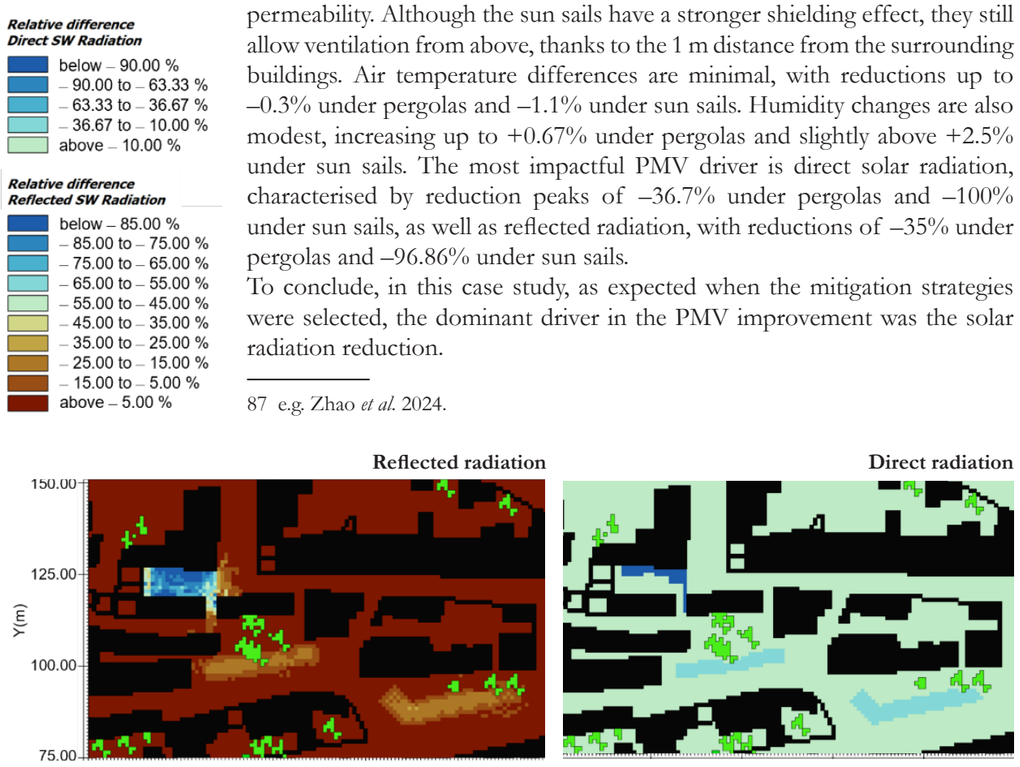



**Fig. 232**
*The percentage difference in reflected radiation and direct radiation between the current scenario and the scenario with the proposed intervention. Each quantity are represented in colours according to the colorbar, the buildings in black, and the vegetation in green. Source: graphic elaboration by Simone Ferrari and Alessandro Santus.*

seen only at peak points.
Adding water sprays to the basic pergola setup improves both the magnitude and extent of PMV reduction, thanks to the diffusion of moisture in the surrounding air. These results confirm the benefits of combining shading and evaporative strategies, as supported by the literature[87].
The results obtained with the pergolas with the high LAD and water sprays, slight increase the improved comfort area and expand the areas showing a PMV peak reduction (around 17.76%), particularly in Piazza Bonapace.
In summary, geometrical shading using sun sails proved to be the most effective strategy in this specific urban context. Shading through vegetation was also beneficial and, as expected, more efficient when using plants with higher LADs. The addition of an evaporative cooling technique via the use of sprays leads to a higher PMV reduction in both cases. However, it raises sustainability concerns: A water consumption of approximately 1 m3/h can be intolerable in Sardinia, due to drought problems. Consequently, the configuration with the higher LAD and without the sprays can be considered as the most suitable in this specific case.
To support this conclusion, this setup is compared with the current state, in terms of relative difference (in %) in the main PMV drivers (Figs. 230, 232). Wind speed is not significantly affected by the pergolas, due to their permeability. Although the sun sails have a stronger shielding effect, they still allow ventilation from above, thanks to the 1 m distance from the surrounding buildings. Air temperature differences are minimal, with reductions up to –0.3% under pergolas and –1.1% under sun sails. Humidity changes are also modest, increasing up to +0.67% under pergolas and slightly above +2.5% under sun sails. The most impactful PMV driver is direct solar radiation, characterised by reduction peaks of –36.7% under pergolas and –100% under sun sails, as well as reflected radiation, with reductions of –35% under pergolas and –96.86% under sun sails.
To conclude, in this case study, as expected when the mitigation strategies were selected, the dominant driver in the PMV improvement was the solar radiation reduction.

87 e.g. Zhao *et al.* 2024.








## Discussion. Towards Possible Operational Guidelines for Climate-Conscious Urban Interventions in Rural Historic Villages

The experimentation carried out in Osidda has shown that, by following a clearly defined methodology grounded in a solid knowledge base, it is possible to act on the main drivers of discomfort and achieve measurable improvements in outdoor comfort by acting on a limited set of spatial levers, provided that the chosen measures remain compatible with the existing built heritage.
The experimental work suggests a sequence of steps that can be generalised:

- In Mediterranean contexts similar to Osidda, in terms of building characteristics and climate, well-placed shading devices should be prioritised as a first lever for mitigation. The Osidda simulations confirmed that light pergolas, vegetated structures and canopies carefully placed and aligned with façades can significantly reduce summer discomfort in Mediterranean historic centres with similar morphological characteristics. However, shading systems must be designed with heritage compatibility in mind. Cover material (opaque, semi-transparent, fabric), fixing systems (reversible, attached to mortar joints rather than stone blocks), and maintenance cycles (cleaning and replacement) should all be taken into account. Artificial shading is more flexible and reversible, while natural shading from trees and climbers offers a different, often more pleasant perceptual quality but entails higher maintenance demands and less adaptability over time. Solutions that require drilling historic stone façades or that obstruct useful ventilation corridors should be rejected;

- Surface materials for paving and façades should be selected carefully, since changes in albedo, emissivity and permeability have a significant microclimatic effect. For sun-exposed squares, materials should be chosen with particular attention to albedo or SRI. Permeability and water infiltration capacity are crucial, especially in sloping areas or zones exposed to intense rainfall, where permeable or semi-permeable systems help reduce runoff and support evaporative cooling. By contrast, pseudo-historic paving solutions in dense, low-permeability materials, such as extensive granite slabs, could worsen both the hydrological and thermal performance of historic streets and squares, and are therefore not advisable;

- Vegetation should be introduced in a targeted way. The experiments confirmed that even limited vegetation can improve comfort if carefully placed in relation to the existing built form and movement patterns. When selecting species and positions, three factors should be considered: water demand (low or medium in drought-prone regions), root development (compatible with stone pavements and retaining walls) and shading potential (height and canopy width at ten years). Species that require regular irrigation in

summer or that risk damaging historic pavements should be avoided. Where trees cannot be planted, pergolas with deciduous climbers offer a flexible alternative. There is also a trade-off between planting mature specimens, which provide immediate benefits at higher cost, and younger plants, which are cheaper but deliver effects only in the medium term;

- Evaporative cooling solutions should be treated with caution. In water-scarce contexts, the volumes required to achieve a substantial cooling effect may conflict with other essential uses and with broader drought-management policies. For this reason, in this study, the guidelines favour low-water strategies and the optimisation of shade and surface properties over water-intensive devices.

To further systematise the observations emerging from the experimental work, a synthetic framework has been developed, intended as a bridge between analytical results and operational guidance (Fig. 233). The framework organises mitigation strategies according to their primary microclimatic mechanisms, typical design elements, and degree of compatibility with historic urban fabrics, while explicitly linking these aspects to design and maintenance considerations. In doing so, it provides a structured reading tool that can assist designers and local administrations in identifying which categories of interventions are most appropriate under specific morphological, climatic, and heritage constraints.

These findings align with the need for explicit integration of outdoor thermal comfort criteria into ordinary planning, building regulations, and conservation instruments for historic districts, so that climate-conscious conservation interventions become standard rather than exceptional practices.

In this perspective, such integration is only feasible if the technical information needed to assess projects is accessible to non-specialist staff. Designers, manufacturers, and suppliers therefore have a decisive role. They should ensure that technical sheets for products used in urban environments explicitly state the parameters that matter in microclimatic terms. These include, at a minimum, solar reflectance (or albedo), emissivity, permeability to water and the increasingly popular Solar Reflectance Index (SRI). Making these parameters explicit would allow local technicians to assess the suitability of materials without needing advanced expertise in building physics. In hot Mediterranean climates, it is very important to check SRI values or albedo of materials, also because part of the literature shows that high-albedo materials may improve indoor conditions but can also increase glare and radiant heat in outdoor spaces. For this reason, values should be evaluated for both indoor and outdoor situations and not only by taking a single building as a case study. What can improve a single indoor microclimate can worsen outdoor conditions, making the situation at the urban scale worse.

On this basis, for any public-space or building intervention in the historic core, even if not explicitly aimed at microclimatic control, the municipality should first undertake at least a basic assessment of local microclimatic behaviour and





then require from project proponents: a concise microclimatic rationale that assesses the microclimate in the selected space; technical sheets of the chosen materials that report key parameters for surfaces (albedo and emissivity, or SRI, and permeability); a statement of compatibility with the historic fabric in terms of reversibility, physico-chemical characteristics, and colour; and a brief maintenance note indicating who can maintain the intervention locally and with which tools. Even where more advanced simulations are not feasible, this minimum documentation would already reduce the risk of interventions that inadvertently worsen thermal conditions or compromise heritage values.

From a methodological point of view, the experimentation contributes to the creation of a protocol that combines microclimate assessment, scenario testing, and design guidance in a form that is usable by small municipalities and design practices. This addresses a recognised gap, contributing new literature on interactions between built heritage and microclimate in historic urban environments in Mediterranean climates, assessing the importance of urban-scale analysis for the development of sustainable interventions in historic settlements, and testing and validating tools and methods to assess the impacts of climate change in historic urban environments.

At the same time, the discussion highlights that the proposed guidelines should not be interpreted as universally applicable solutions. Their effectiveness depends on the presence of a compact urban fabric, on the relative stability of spatial configurations, and on climatic conditions comparable to those of the Mediterranean inland context examined. In more dispersed settlements, in highly transformed historic centres, or under markedly different climatic regimes, the relative weight of the mitigation strategies and their interactions may vary. For this reason, the framework is intended to support informed decision-making rather than to replace site-specific analysis.

The ENVI-met simulations and GIS-based analyses allowed alternative mitigation strategies to be compared before resources were committed, which is particularly important in contexts with limited budgets and high heritage constraints. The comparative testing of scenarios showed that different combinations of shading, materials, and vegetation offer distinct trade-offs, and that these can be made explicit and discussed with stakeholders. In this sense, the protocol functions both as an analytical tool and as a platform for negotiation between conservation requirements and climate adaptation needs.

| Category of mitigation strategies | Main influencing factors | Main influenced factors | Possible mitigation elements | Compatibility with the historic environment | Reccomendations |
|---|---|---|---|---|---|
| **Urban geometry** | Urban canyon aspect ratio; street orientation; building aspect ratio; street orientation; roof and courtyard geometry; façade continuity | Modifies ventilation, shading, and the Sky View Factor (SVF); affects solar access and radiation trapping | Modification of urban patterns<br>Creation of voids for airflow<br>Building height adaptations<br>Use of balconies for shading<br>Recovery or reopening of courtyards | **Limited** | Have to be carefully tailored on the urban fabric characteristics, considering the urban stratigraphy and the historical value of the interested areas |
| **Temporary urban geometric elements** | Positioning and geometry of the designed elements | Control of solar radiation and ventilation | Windbreak structures<br>Wind-catchers<br>Removable shading devices | **High** | Have to be reversible, low-impact, and visually compatible with the context, enhancing rather than obscuring it |
| **Greening (vegetation-based solutions)** | Surface albedo; LAD; positioning, quantity, maturity, and species of the elements | Provides shading and modifies airflow (passive effect); reduces air temperature through evapotranspiration and increases relative humidity (active effect). | Green roofs<br>Green walls<br>Green pavements<br>Vegetated pergolas<br>Planting trees, bushes or edges | **High** | The type of vegetation have to be carefully selected (e.g. dimension of the roots, seasonality, type of fruits) and carefully placed within the urban environment; mantainance, costs, and overall sustainability must be taken into account |
| **Surfaces and materials** | Surface albedo, emissivity, permeability, thermal conductivity, roughness and color | Heat storage and surface reflectivity; radiative balance of streets and façades | High-reflectance coatings, cool materials, and retro-reflective coatings<br>Permeable or porous surfaces | **Medium** | Materials should be compatible with existing ones; the effectiveness of the intervention on the microclimate at different scales must be carefully evaluated; the visual compatibility should be taken into account |
| **Evaporative cooling** | Used quantity of water; evaporative potential | Lowers air temperature by increasing latent heat flux from water evaporation; relative humidity | Artificial water bodies (fountains, shallow basins)<br>Misting systems (water sprays) | **Medium** | Local relative humidity should be carefully assessed to prevent negative effects; mantainance, costs, and overall sustainability must be taken into account |

**Fig. 233**
*Framework for outdoor microclimate mitigation strategies and their applicability in historic urban contexts. The matrix classifies the categories of mitigation measures against main influencing factors, primary effects on microclimate, typical mitigation elements, indicative compatibility with heritage settings, and key recommendations for design and maintenance. The framework is intended to support decision-making in contexts where climatic adaptation and heritage conservation constraints coexist. Source: author's elaboration based on the literature review.*

## Conclusions

This thesis has addressed the growing challenge of adapting historic settlements to emerging climatic pressures while preserving their cultural, architectural, and landscape values. Mediterranean historic villages, particularly those located in inland areas, are increasingly exposed to rising temperatures, heat stress and demographic decline, yet they often lack operational tools that integrate climate adaptation within conservation and planning frameworks. While a substantial body of literature has examined microclimate mitigation strategies and heritage conservation separately, their integration at the scale of small historic settlements remains limited, particularly within ordinary municipal planning and decision-making processes. This research responds to this gap by positioning outdoor thermal comfort as a bridge between environmental performance, everyday liveability, and conservation practice.

Against this background, the thesis set out to develop and test a climate-sensitive conservation protocol for Mediterranean historic villages that integrates conservation principles with microclimatic assessment and can be applied within municipal planning and conservation processes. The research was guided by three main questions: how a settlement-scale protocol can coherently integrate heritage values, spatial constraints, and microclimatic evidence; which morphological, material, and vegetation-related factors most influence local microclimatic conditions in compact historic villages; and to what extent heritage-compatible mitigation measures can improve outdoor thermal comfort, and how their effectiveness can be evaluated.

To address these questions, the research pursued three objectives: the development of a structured settlement-scale protocol integrating conservation and microclimatic assessment; the identification of the main drivers of local microclimatic conditions through integrated architectural, landscape and GIS-based diagnostics supported by simulation; and the testing and comparison of heritage-compatible mitigation scenarios translated into decision-support outputs for planning and design.

The results of the research demonstrate that outdoor thermal comfort in historic villages is strongly shaped by a set of settlement-scale factors, notably solar exposure, street geometry, material properties of ground and façades, and the presence and configuration of vegetation. Microclimatic simulations confirmed that carefully designed, heritage-compatible measures can significantly reduce thermal stress, even without altering the historic morphology of the settlement. In particular, shading strategies emerged as the most effective first lever for mitigation, followed by targeted greening, while surface treatments and evaporative solutions require more cautious and context-dependent application.

Through comparative scenario testing, the research demonstrated that the effectiveness of mitigation strategies cannot be assumed a priori, but must be evaluated in relation to local morphology, materials, climate and patterns of use. The protocol developed in the thesis responds to this need by bringing





together diagnostic analysis, simulation-based testing and design guidance within a coherent workflow. In doing so, it provides a means to translate abstract climate-adaptation goals into concrete, assessable interventions that remain compatible with heritage constraints. The research questions posed at the outset are therefore addressed by showing that a settlement-scale, climate-sensitive conservation protocol is both needed and feasible, that key microclimatic drivers can be systematically identified, and that the impacts of mitigation measures can be evaluated before implementation.

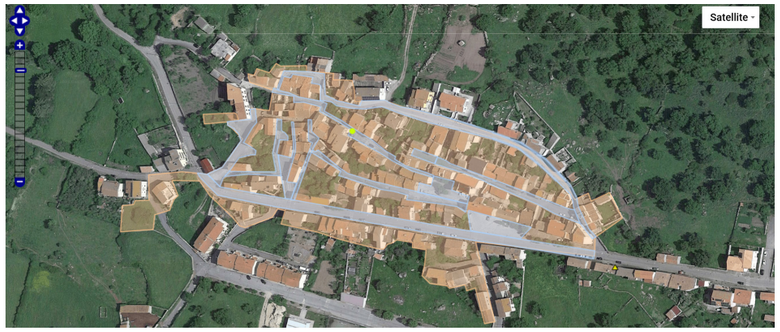
The thesis makes several contributions to knowledge. First, it advances the integration of outdoor microclimatic assessment within conservation practice at the scale of historic settlements, moving beyond building-focused approaches. Second, it contributes empirical evidence on the interaction between morphology, materials, vegetation, and outdoor thermal comfort in Mediterranean inland villages, a context that remains underrepresented in the literature. Third, it proposes an operational framework accompanied by structured guidance to support small municipalities and practitioners working under resource and regulatory constraints.

At the same time, important limitations and directions for further research must be recognised. Improved microclimatic conditions alone do not reverse depopulation or economic decline. Rather, they remove a significant barrier to everyday liveability and reuse, acting as a necessary but not sufficient condition for broader regeneration strategies. The climatic protocol proposed here should therefore be understood as complementary to wider social, economic, and infrastructural policies addressing the structural drivers of out-migration. In addition, the ENVI-met simulations and GIS-based analyses represent snapshots based on specific boundary conditions and timeframes. Given that climate change is a moving target, effective adaptation will require continuous monitoring, feedback mechanisms and capacity building within local administrations, allowing guidelines to be periodically updated as climatic conditions evolve.

Finally, by demonstrating that climate-sensitive conservation is operationally feasible at the scale of small historic settlements, this thesis offers a step towards a more integrated approach in which the protection of historic form and materials goes hand in hand with environmental comfort and resilience. Future research could extend this work through comparative applications in other Mediterranean and non-Mediterranean contexts, through long-term and seasonal monitoring of implemented measures, and through closer integration of social research on perceptions, practices, and uses of public space. Together, these developments could further strengthen the role of climate-conscious conservation as a tool for sustaining the everyday life of historic settlements under conditions of environmental change.

# Attachment 1.
# Carta del Rischio

## Example of a Completed Form - Via Mazzini, Osidda




**Dettaglio Spazi Urbani** *(ID: 11)*

### *Localisation and Anagraphic Data*

| Centro Storico di Riferimento | | | |
|---|---|---|---|
| **Regione** | Sardegna | **Provincia** | Nuoro |
| **Comune** | Osidda | **Denominazione** | Centro Storico di Osidda |
| **Località** | | | |

**Ubicazione**

**Unità Urbane Prospicienti**

| Descrizione | | | |
|---|---|---|---|
| **Denominazione** | Via Mazzini | **Categoria Generale** | spazio pubblico |
| **Categoria Specifica** | via | | |

| | | | |
|---|---|---|---|
| **Accessibilità** | totalmente accessibile | | |

**Funzioni Generiche U.U.**

residenze

in abbandono

attività produttive/servizi

turismo

| Geolocalizzazione | | | |
|---|---|---|---|
| **Sistema di Riferimento** | WGS84 | **Cartografia** | |
| **X Centroide** | 9.21760391858295 | **Y Centroide** | 40.524592318318 |
| **Metodologia di Perimetrazione** | Individuazione limiti della via | | |

### *Urban system*

| Impianto | | | |
|---|---|---|---|
| **Configurazione Impianto (*)** | rettilinea | | |

**Margini**

Unità Urbana

| | | | |
|---|---|---|---|
| **Sezione Verticale Trasversale** | continua piana | **Sezione Verticale Longitudinale** | continua inclinata |

**Elementi Di Arredo Urbano**

panchina

**Sistema D'Illuminazione**

lampioni

corpi illuminanti a parete

### *Dimensional data*

| | | | |
|---|---|---|---|
| **Altezza Minima (m)** | | **Altezza Massima (m)** | |
| **Larghezza (m)** | 4 | **Lunghezza (m)** | 160 |
| **Superficie (mq)** | 630 | **Larghezza Media Sezione Stradale (m)** | 4 |
| **Superficie Area Verde o Spazio Pubblico Attrezzato (mq)** | 18 | | |

### *Natural/ Artificial System and Transformations*

| Elementi Artificiali e Naturali | | | |
|---|---|---|---|

**Pavimentazioni Tradizionali E Storiche**

acciottolato

**Pavimentazioni Moderne**

lastre lapidee piane regolari

| | | | |
|---|---|---|---|
| **Incidenza Pavimentazioni Moderne** | 1-20% | **Incidenza Elementi di Arredo Moderni** | 81-100% |

| | | | |
|---|---|---|---|
| **Incidenza Aree a Verde** | 0% | **Incidenza Aree a Verde Storico** | 0% |
| **Specifiche e Note** | | | |

**Infrastrutture Impiantistiche E Urbane Sotterranee**

rete idrica

rete elettrica/telecomunicazioni

rete fognaria

| | | | |
|---|---|---|---|
| **Incidenza Sistemi d'Illuminazione Compatibili** | media | **Specifiche e Note** | |
| **Indice di Modifiche e Trasformazioni** | | | |

| **Indice** | | | |
|---|---|---|---|
| **Modifiche e Trasformazioni Globale** | 0.38 medio | **Data** | 11-06-2025 |
| **Sotto-indici Tematici** | | | |
| **Modifiche e Trasformazioni Elementi Artificiali** | 0.60 medio | | |
| **Modifiche e Trasformazioni Elementi Naturali** | 0.00 basso | | |
| **Presenza Sistemi d'Illuminazione Incongrui** | 0.50 medio | | |

| **Indice** | | | |
|---|---|---|---|
| **Vulnerabilità** | 0.28 basso | **Data** | 11-06-2025 |
| **Sotto-indici Tematici** | | | |
| **Vulnerabilità dei Fronti Urbani** | 0.50 medio | | |
| **Degrado e Dissesti nel Piano** | 0.07 basso | | |
| **Degrado Elementi di Arredo e Sistemi d'Illuminazione** | 0.20 basso | | |

## *Historical Data*

**Cronologia**

| Rif. Intero/Pa.. | Sec. Inizio | Fraz. Sec. Ini.. | Data Inizio | Valid. Inizio | Sec. Fine | Fraz. Sec. Fi.. | Data Fine | Valid. Fine | Nc |
|---|---|---|---|---|---|---|---|---|---|
| | XIX | prima metà | 1848 | ante | XIX | prima metà | 1848 | ante | Cartog |

| Tipo | Contenuto | Riferimento Cronologico | Cc |
|---|---|---|---|
| Documento archivistico | Mappa catastale storica | 1848 | AS.NU |
| Documento archivistico | Mappa catastale storica | 1960 | AS-NU |

## *Degradation and Structural Instabilities*

Normative () Allegati ()

| | | | |
|---|---|---|---|
| **Manutenzione Aree Verdi** | | **Incidenza Degrado Superficiale (fronti di UU prospicienti)** | 41-60% |
| **Incidenza Dissesti in Elevato (fronti di UU prospicienti)** | 21-40% | **Incidenza Dissesti in Piano** | 0% |
| **Incidenza Degrado Pavimentazioni** | 1-20% | **Incidenza Degrado degli Elementi di Arredo** | 1-20% |

| | | | |
|---|---|---|---|
| **Incidenza Degrado nel Sistema d'Illuminazione** | 1-20% | **Incidenza Degrado negli Elementi di Raccordo dei Livelli** | 0% |
| **Specifiche e Note** | | | |

## *Legislation*

| Tipo | Data Vincolo |
|---|---|
| In area di interesse culturale verificato | 2006 |

| | |
|---|---|
| **Specifiche e Note** | Parte del Centro di Prima e Antica Formazione, PPR approvato con delibera del 05 settembre 2006, n.36/7 |

**Strumenti Urbanistici**

| Ente/Amministrazione | Tipo E Indicazioni Strumento | Riferimento Web |
|---|---|---|
| Comune di Osidda | Piano Urbanistico Comunale 1999 | |
| Comune di Osidda | Piano Particolareggiato del Centro Storico 2002 | |
| Comune di Osidda | Piano Particolareggiato del Centro Matrice 2015 | |

**Compilazione**

| | | | |
|---|---|---|---|
| **Nome Compilatore (*)** | Giulia Cherchi | **Ente Compilatore** | DICAAR Università degli Studi di Cagliari |
| **Data Compilazione (*)** | 11-06-2025 | | |

# Attachment 2.
# ENVI-met Materials and Vegetation Database

## Walls

Database-ID: [0200GR]
Name: Brick: granit
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.60000 |
| Absorption | 0.70000 |
| Transmission | 0.00000 |
| Reflection | 0.30000 |
| Emissivity | 0.45000 |
| Specific Heat | 836.00000 |
| Thermal Conductivity | 3.20000 |
| Density | 2500.00000 |
| Extra ID | 0 |

Database-ID: [02CRPL]
Name: Cement Plaster
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.03000 |
| Absorption | 0.60000 |
| Transmission | 0.00000 |
| Reflection | 0.40000 |
| Emissivity | 0.90000 |
| Specific Heat | 1000.00000 |
| Thermal Conductivity | 1.40000 |
| Density | 2000.00000 |
| Extra ID | 0 |

Database-ID: [02LMPL]
Name: Lime Plaster
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.03000 |
| Absorption | 0.60000 |
| Transmission | 0.00000 |
| Reflection | 0.40000 |
| Emissivity | 0.96000 |
| Specific Heat | 960.00000 |
| Thermal Conductivity | 0.45000 |
| Density | 1800.00000 |
| Extra ID | 0 |

Database-ID: [0200C3]
Name: Concrete: hollow block
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.30000 |
| Absorption | 0.70000 |
| Transmission | 0.00000 |
| Reflection | 0.30000 |
| Emissivity | 0.94000 |
| Specific Heat | 840.00000 |
| Thermal Conductivity | 0.86000 |
| Density | 930.00000 |
| Extra ID | 0 |

Database-ID: [020GBS]
Name: Glass + Brise soleil
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.00200 |
| Absorption | 0.25000 |
| Transmission | 0.60000 |
| Reflection | 0.15000 |
| Emissivity | 0.90000 |
| Specific Heat | 1200.00000 |
| Thermal Conductivity | 0.80000 |
| Density | 1500.00000 |
| Extra ID | 0 |

Name: Reflective Coating
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.00034 |
| Absorption | 0.05000 |
| Transmission | 0.00000 |
| Reflection | 0.95000 |
| Emissivity | 0.91000 |
| Specific Heat | 1265.69995 |
| Thermal Conductivity | 0.61300 |
| Density | 1639.00000 |
| Extra ID | 0 |

## Roofs

Database-ID: [0200RC]
Name: Roofing: tile "Coppo
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.05000 |
| Absorption | 0.60000 |
| Transmission | 0.00000 |
| Reflection | 0.40000 |
| Emissivity | 0.90000 |
| Specific Heat | 800.00000 |
| Thermal Conductivity | 0.84000 |
| Density | 1900.00000 |
| Extra ID | 0 |

Database-ID: [02LMMR]
Name: Lime Mortar
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.01000 |
| Absorption | 0.60000 |
| Transmission | 0.00000 |
| Reflection | 0.40000 |
| Emissivity | 0.96000 |
| Specific Heat | 960.00000 |
| Thermal Conductivity | 1.11000 |
| Density | 2100.00000 |
| Extra ID | 0 |

Database-ID: [0200RE]
Name: Reeds
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.03000 |
| Absorption | 0.70000 |
| Transmission | 0.00000 |
| Reflection | 0.30000 |
| Emissivity | 0.90000 |
| Specific Heat | 1200.00000 |
| Thermal Conductivity | 0.06300 |
| Density | 150.00000 |
| Extra ID | 0 |

Database-ID: [0200RT]
Name: Roofing: tile "Tegole
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.05000 |
| Absorption | 0.70000 |
| Transmission | 0.00000 |
| Reflection | 0.30000 |
| Emissivity | 0.90000 |
| Specific Heat | 800.00000 |
| Thermal Conductivity | 0.84000 |
| Density | 1900.00000 |
| Extra ID | 0 |

Database-ID: [0200C1]
Name: Concrete
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.15000 |
| Absorption | 0.70000 |
| Transmission | 0.00000 |
| Reflection | 0.30000 |
| Emissivity | 0.94000 |
| Specific Heat | 840.00000 |
| Thermal Conductivity | 1.30000 |
| Density | 2000.00000 |
| Extra ID | 0 |

Database-ID: [0200CT]
Name: Roofing: ceramic tile
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.05000 |
| Absorption | 0.70000 |
| Transmission | 0.00000 |
| Reflection | 0.30000 |
| Emissivity | 0.90000 |
| Specific Heat | 800.00000 |
| Thermal Conductivity | 1.20000 |
| Density | 2000.00000 |
| Extra ID | 0 |

Database-ID: [0200BM]
Name: Roofing: Bituminous Membrane
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.05000 |
| Absorption | 0.80000 |
| Transmission | 0.00000 |
| Reflection | 0.20000 |
| Emissivity | 0.90000 |
| Specific Heat | 800.00000 |
| Thermal Conductivity | 0.23000 |
| Density | 2000.00000 |
| Extra ID | 0 |

Database-ID: [020FBC]
Name: Fiber Cement
Color:

| Parameter | Value |
|---|---|
| Default Thickness | 0.30000 |
| Absorption | 0.70000 |
| Transmission | 0.00000 |
| Reflection | 0.30000 |
| Emissivity | 0.94000 |
| Specific Heat | 840.00000 |
| Thermal Conductivity | 0.30000 |
| Density | 1500.00000 |
| Extra ID | 0 |

## Natural surfaces

Database-ID: [0200ST]
Name: Sandy Clay
Color:

| Parameter | Value |
|---|---|
| Typ of material | Natural soil |
| Water content at saturation | 0.42600 |
| Water content at field capac | 0.31000 |
| Water content at wilting poi | 0.21900 |
| Matrix potential | -0.15300 |
| Hydraulic conductivity | 2.20000 |
| Volumetric heat capacity | 1.17500 |
| Clapp & Hornberger Constar | 10.40000 |
| Heat Conductivity | 0.00000 |
| Additional Value 1 | 0.00000 |
| Additional Value 2 | 0.00000 |

Database-ID: [0200XX]
Name: Grass 25 cm aver. dense
Color:

| Parameter | Value |
|---|---|
| Alternative Name | (None) |
| CO2 Fixation Type | C3 |
| Leaf Type | Gras |
| Albedo | 0.20000 |
| Emissivity | 0.97000 |
| Transmittance | 0.30000 |
| Plant height | 0.25000 |
| Root Zone Depth | 0.20000 |
| Costs | 0.00000 |
| Leaf Area (LAD) Profile | 0.30000,0.30000,0.30000,0.30000,0.30000,0.3 |
| Root Area (RAD) Profile | 0.10000,0.10000,0.10000,0.10000,0.10000,0.1 |
| Season Profile | 1.00000,1.00000,1.00000,1.00000,1.00000,1.0 |

## Street pavements

Database-ID: [0200GC]
Name: Granite Pavement (cobble)
Color:

| Parameter | Value |
|---|---|
| z0 Roughness Length | 0.02000 |
| Albedo | 0.25000 |
| Emissivity | 0.93000 |
| ExtraID | 0 |
| Surface is irrigated | False |
| Costs | 0.00000 |
| Water: Mixing Coefficient | 0.00100 |
| Water: Turbidity/Extinction | 2.10000 |

Database-ID: [0200GS]
Name: Granit Pavement (single stones)
Color:

| Parameter | Value |
|---|---|
| z0 Roughness Length | 0.01000 |
| Albedo | 0.35000 |
| Emissivity | 0.90000 |
| ExtraID | 0 |
| Surface is irrigated | False |
| Costs | 0.00000 |
| Water: Mixing Coefficient | 0.00100 |
| Water: Turbidity/Extinction | 2.10000 |

Database-ID: [0200PG]
Name: Concrete Pavement Gray
Color:

| Parameter | Value |
|---|---|
| z0 Roughness Length | 0.01000 |
| Albedo | 0.30000 |
| Emissivity | 0.90000 |
| ExtraID | 0 |
| Surface is irrigated | False |
| Costs | 0.00000 |
| Water: Mixing Coefficient | 0.00100 |
| Water: Turbidity/Extinction | 2.10000 |

Database-ID: [0200ST]
Name: Asphalt Road
Color:

| Parameter | Value |
|---|---|
| z0 Roughness Length | 0.01000 |
| Albedo | 0.12000 |
| Emissivity | 0.90000 |
| ExtraID | 0 |
| Surface is irrigated | False |
| Costs | 0.00000 |
| Water: Mixing Coefficient | 0.00100 |
| Water: Turbidity/Extinction | 2.10000 |

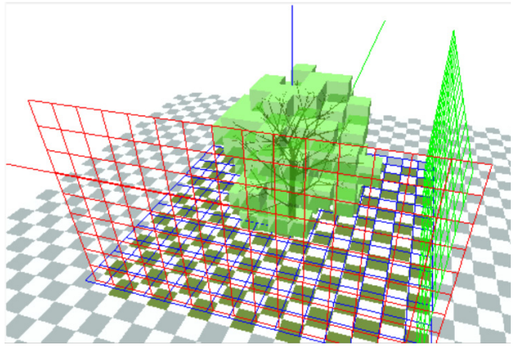
Database-ID: [0100TB]
Name: LEGACY: Terre battue (Smashed brick)
Color:

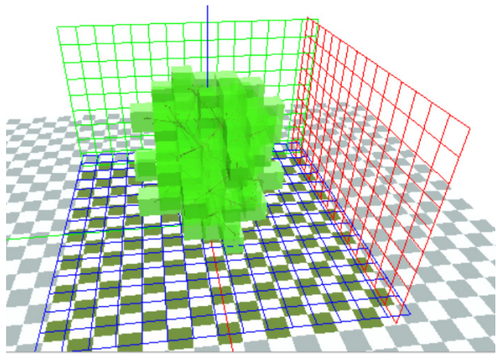
| Parameter | Value |
|---|---|
| z0 Roughness Length | 0.01000 |
| Albedo | 0.40000 |
| Emissivity | 0.90000 |
| ExtraID | 0 |
| Surface is irrigated | False |
| Costs | 0.00000 |
| Water: Mixing Coefficient | 0.00100 |
| Water: Turbidity/Extinction | 2.10000 |

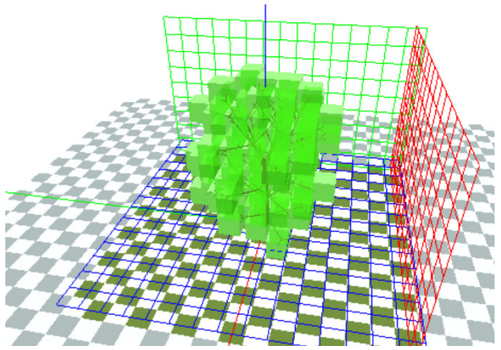
# Vegetation

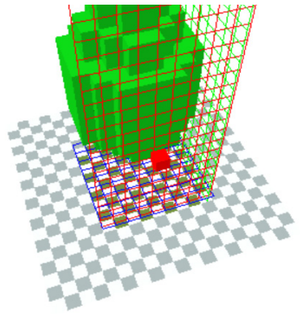
Database-ID: [0200H2]
Name: Hedge dense, 2m
Color:

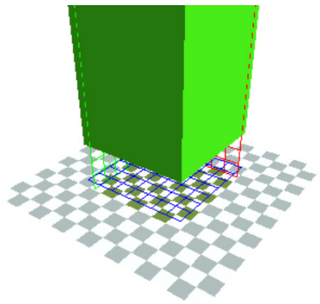
| Parameter | Value |
|---|---|
| Alternative Name | (None) |
| CO2 Fixation Type | C3 |
| Leaf Type | Deciduous |
| Albedo | 0.20000 |
| Emissivity | 0.97000 |
| Transmittance | 0.30000 |
| Plant height | 2.00000 |
| Root Zone Depth | 1.00000 |
| Costs | 0.00000 |
| Leaf Area (LAD) Profile | 1.00000,1.00000,1.00000,1.00000,1.00000,1.0 |
| Root Area (RAD) Profile | 0.10000,0.10000,0.10000,0.10000,0.10000,0.1 |
| Season Profile | 1.00000,1.00000,1.00000,1.00000,1.00000,1.0 |

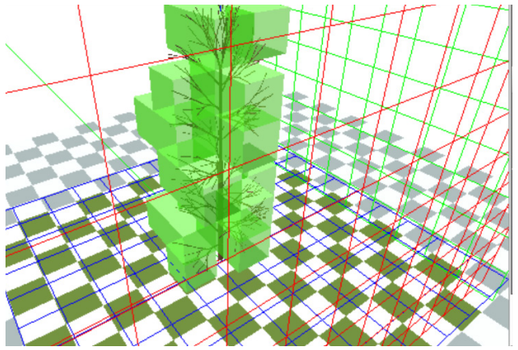




General Information
ID: 0100P7 Color:
Name: Pine Tree 7m
*Alternative Name:* *Pinus sylvestris*
Leaf Type: Conifer
Author: *(Enter Author of Tree Model)*
Cost per plant: 0,00
Edit Physical Properties... Apply Settings

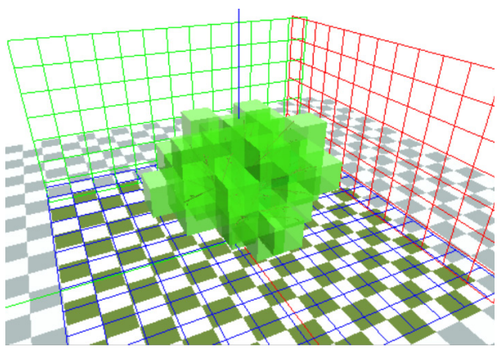
Plant Geometry
Geometry: QSM Tree
Height (m): 7.30 m
Width (m): 3.05 x 3.10 m (Tree Extent)
Number of Cells: 11 x 11 x 9 (1x1 m)

Tree Calendar

| Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

| Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Edit L-System
L-System Editor...
Rebuilt Tree Data



General Information
ID: 020FTS Color:
Name: Fruit Tree 5m
*Alternative Name:* *(none)*
Leaf Type: Deciduous
Author: *(Enter Author of Tree Model)*
Cost per plant: 0,00
Edit Physical Properties... Apply Settings

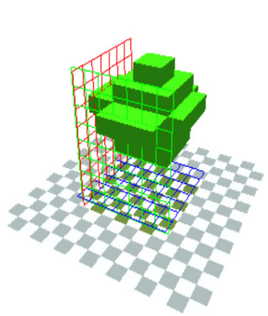
Plant Geometry
Geometry: QSM Tree
Height (m): 5.07 m
Width (m): 5.02 x 5.42 m (Tree Extent)
Number of Cells: 13 x 13 x 7 (1x1 m)

Tree Calendar

| Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|
| 0.30 | 0.30 | 0.30 | 0.40 | 0.70 | 1.00 |

| Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|
| 1.00 | 1.00 | 0.80 | 0.60 | 0.30 | 0.30 |

Edit L-System
L-System Editor...
Rebuilt Tree Data



General Information
ID: 000PA8 Color:
Name: LEGACY: Populus Alba 8m
*Alternative Name:* *Silverleaf Poplar*
Leaf Type: Deciduous
Author: *(Enter Author of Tree Model)*
Cost per plant: 0,00
Edit Physical Properties... Apply Settings

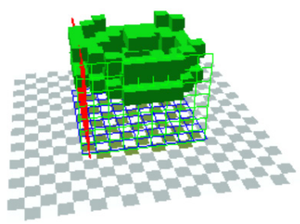
Plant Geometry
Geometry: Grid Based
Height (m): 8.00
Width (m): 7.00
Number of Cells: 7 x 7 x 8 (1x1 m)

Tree Calendar

| Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

| Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Edit Grid Matrix
Grid based trees can be edited using the cursor in the 3-table projection.
**LAD value to be assigned:** 1
Use left Mouse to assign value, right Mouse to delete



General Information
ID: 0000CS Color:
Name: LEGACY: Cercis Siliquastrum
*Alternative Name:* *Judas Tree*
Leaf Type: Deciduous
Author: *(Enter Author of Tree Model)*
Cost per plant: 0,00
Edit Physical Properties... Apply Settings

Plant Geometry
Geometry: Grid Based
Height (m): 7.00
Width (m): 9.00
Number of Cells: 9 x 9 x 7 (1x1 m)

Tree Calendar

| Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

| Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|
| 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

Edit Grid Matrix
Grid based trees can be edited using the cursor in the 3-table projection.
**LAD value to be assigned:** 1
Use left Mouse to assign value, right Mouse to delete

# Attachment 3.
# Hourly PMV Record of the Simulated Summer Typical Critical Days

### 2024 model 2024 climate

| hour | $PMV_{max}$ |
|---|---|
| 6 | 0,20 |
| 7 | 3,55 |
| 8 | 5,39 |
| 9 | 6,30 |
| 10 | 8,03 |
| 11 | 8,50 |
| 12 | 9,12 |
| 13 | 9,43 |
| 14 | 9,45 |
| 15 | 9,15 |
| 16 | 8,77 |
| 17 | 7,96 |
| 18 | 5,98 |
| 19 | 2,96 |
| 20 | 1,00 |
| 21 | 0,45 |
| 22 | 0,02 |
| 23 | -0,22 |
| 0 | -0,63 |
| 1 | -0,91 |
| 2 | -1,18 |
| 3 | -1,42 |
| 4 | -1,49 |
| 5 | -1,31 |

### 2024 model 1940 climate

| h | PMVmax |
|---|---|
| 6 | -2,32 |
| 7 | 1,47 |
| 8 | 3,41 |
| 9 | 4,73 |
| 10 | 5,79 |
| 11 | 6,28 |
| 12 | 6,77 |
| 13 | 7,33 |
| 14 | 7,27 |
| 15 | 7,12 |
| 16 | 6,91 |
| 17 | 5,86 |
| 18 | 3,81 |
| 19 | 0,75 |
| 20 | -0,15 |
| 21 | -0,69 |
| 22 | -1,02 |
| 23 | -1,35 |
| 0 | -1,61 |
| 1 | -1,84 |
| 2 | -2,01 |
| 3 | -2,15 |
| 4 | -2,26 |
| 5 | -2,26 |

### 1939 model 1940 climate

| hour | $PMV_{max}$ |
|---|---|
| 6 | -2,41 |
| 7 | 1,41 |
| 8 | 3,34 |
| 9 | 4,63 |
| 10 | 5,49 |
| 11 | 6,04 |
| 12 | 6,50 |
| 13 | 7,05 |
| 14 | 7,04 |
| 15 | 6,86 |
| 16 | 6,44 |
| 17 | 5,43 |
| 18 | 3,70 |
| 19 | 0,36 |
| 20 | -0,51 |
| 21 | -0,97 |
| 22 | -1,26 |
| 23 | -1,55 |
| 0 | -1,78 |
| 1 | -1,98 |
| 2 | -2,13 |
| 3 | -2,27 |
| 4 | -2,38 |
| 5 | -2,36 |

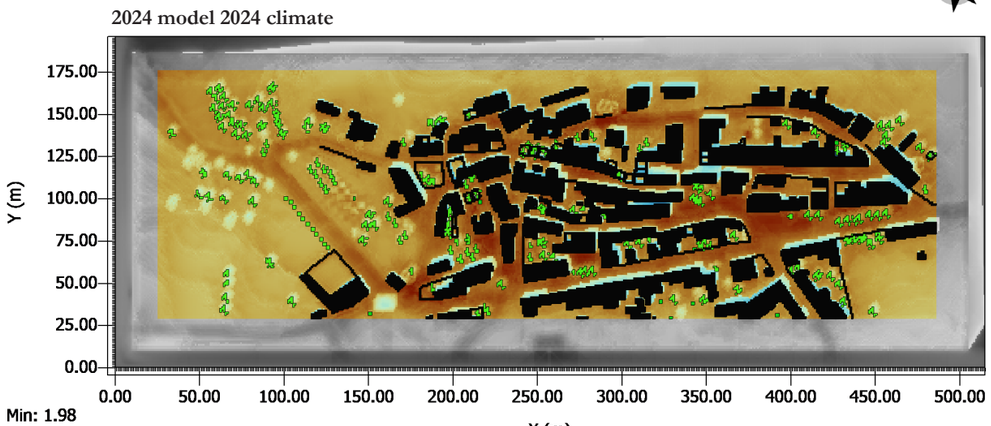
### 1939 model 2024 climate

| hour | PMVmax |
|---|---|
| 6 | 0,27 |
| 7 | 3,34 |
| 8 | 5,15 |
| 9 | 6,74 |
| 10 | 7,57 |
| 11 | 8,59 |
| 12 | 9,31 |
| 13 | 9,26 |
| 14 | 9,17 |
| 15 | 8,97 |
| 16 | 8,49 |
| 17 | 7,72 |
| 18 | 5,89 |
| 19 | 2,81 |
| 20 | 0,65 |
| 21 | 0,15 |
| 22 | -0,24 |
| 23 | -0,45 |
| 0 | -0,82 |
| 1 | -1,07 |
| 2 | -1,31 |
| 3 | -1,53 |
| 4 | -1,59 |
| 5 | -1,42 |

# Attachment 4.
# Urban Microclimate Simulations Outcomes. Comparative Analysis

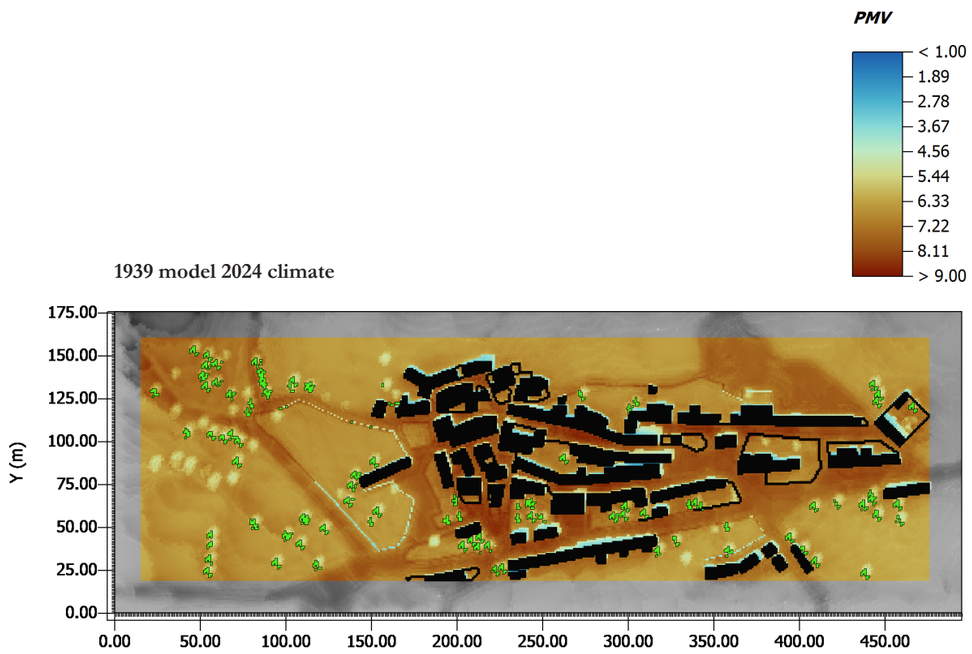
## Summer, 14:00. PMV

2024 model 2024 climate



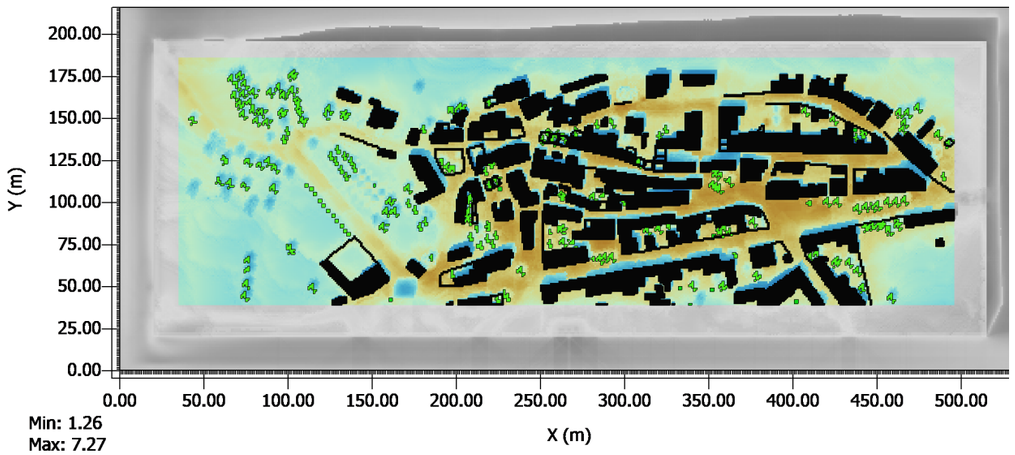

Min: 1.98
Max: 9.45

1939 model 2024 climate



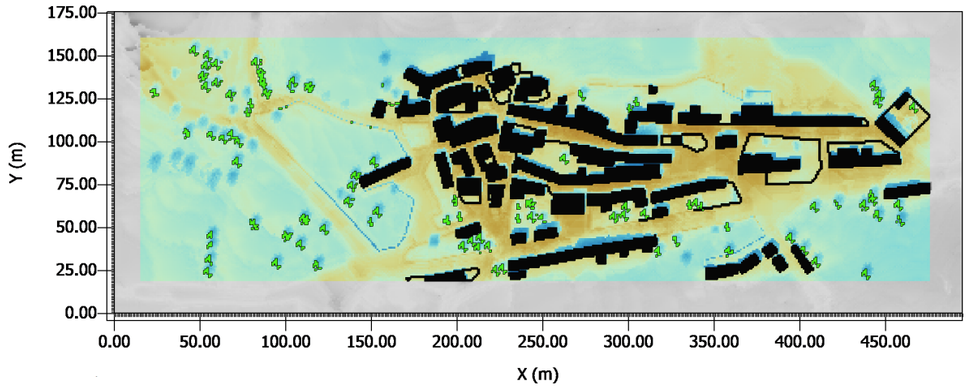

Min: 2.13
Max: 9.17

2024 model 1940 climate




Min: 1.26
Max: 7.27

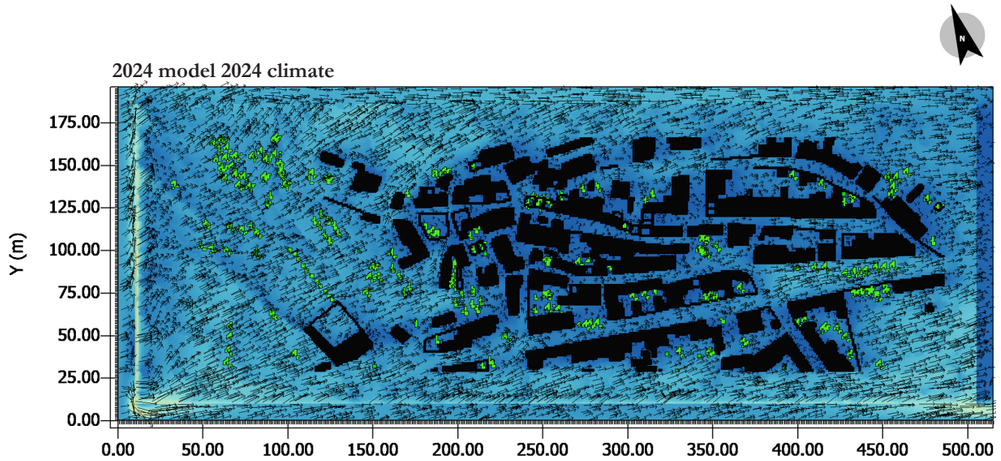
1939 model 1940 climate




Min: 1.29
Max: 7.04

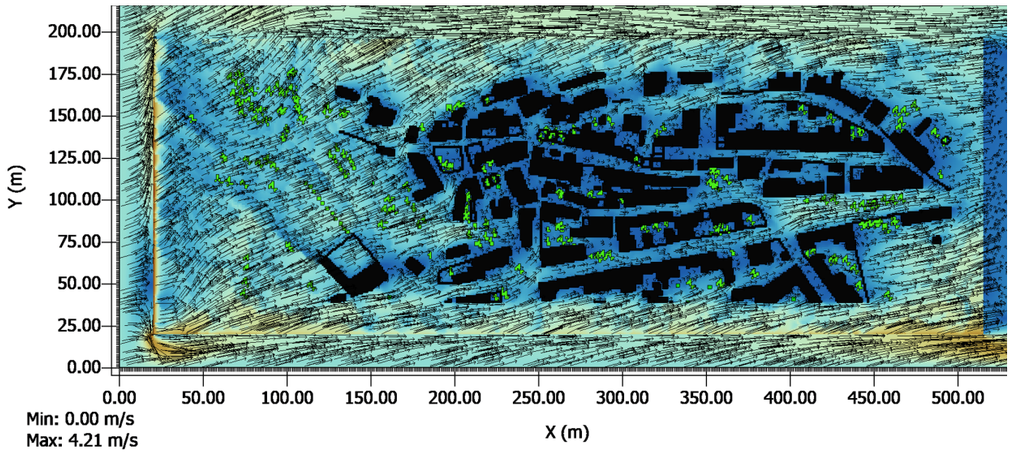
## Summer, 14:00. Wind

2024 model 2024 climate

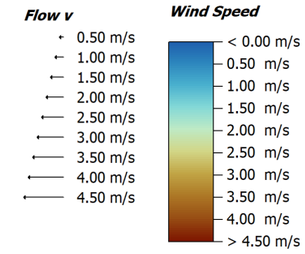



Min: 0.00 m/s
Max: 2.89 m/s

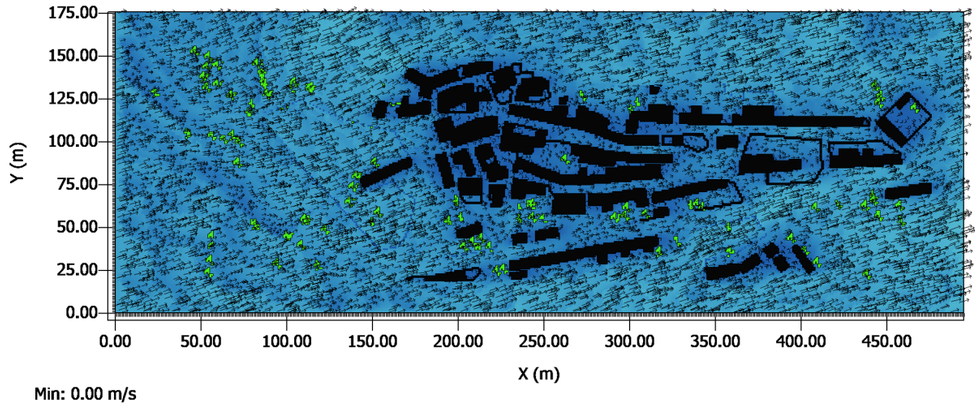
2024 model 1940 climate




Min: 0.00 m/s
Max: 4.21 m/s

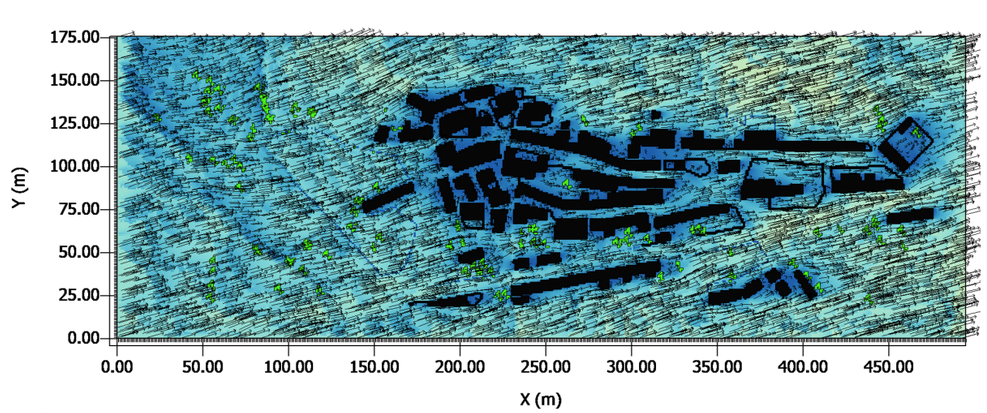



1939 model 2024 climate




Min: 0.00 m/s
Max: 1.16 m/s

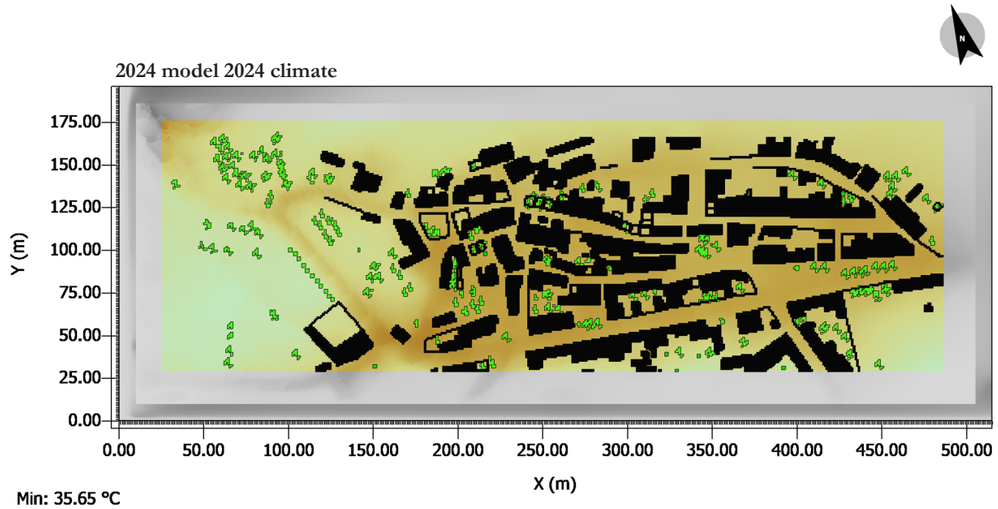
1939 model 1940 climate




Min: 0.00 m/s
Max: 2.24 m/s

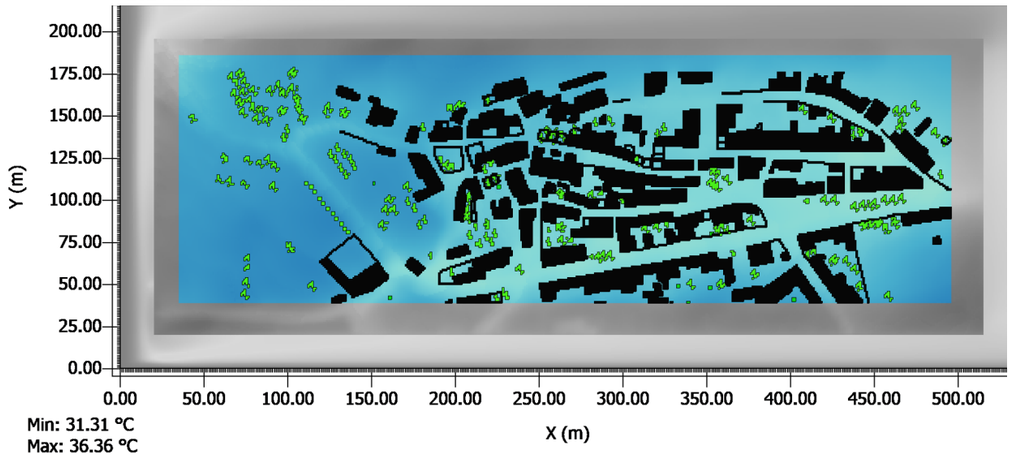
## Summer, 14:00. Air temperature

2024 model 2024 climate

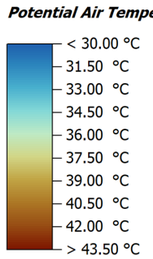



Min: 35.65 °C
Max: 40.70 °C

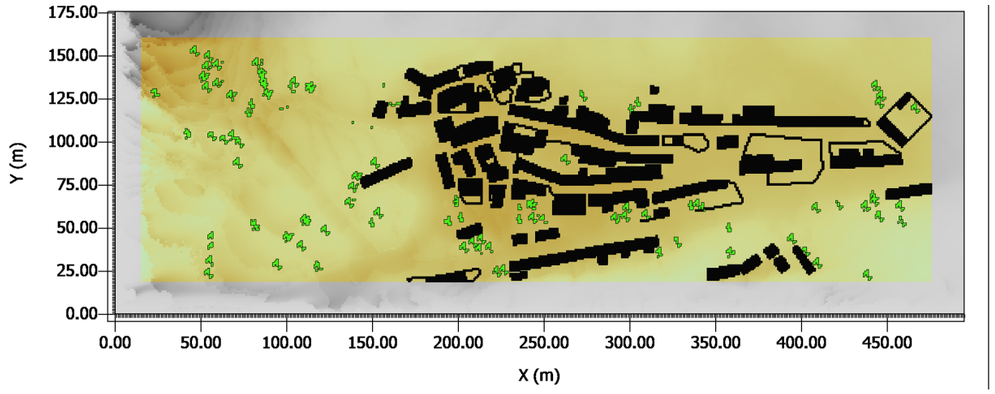
2024 model 1940 climate




Min: 31.31 °C
Max: 36.36 °C

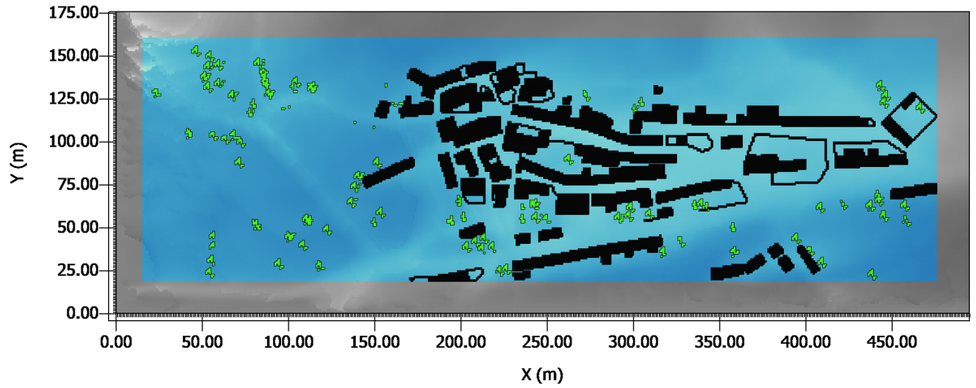



1939 model 2024 climate




Min: 36.17 °C
Max: 42.59 °C

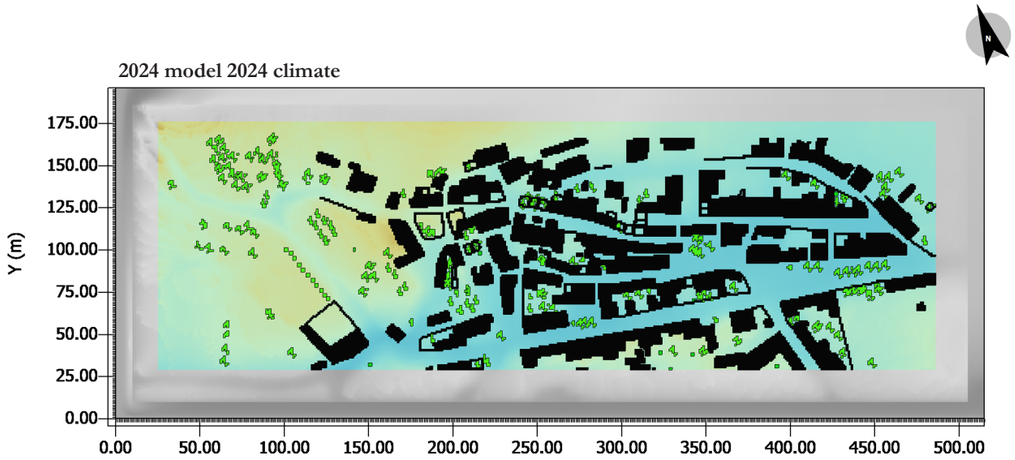
1939 model 1940 climate




Min: 30.99 °C
Max: 37.07 °C

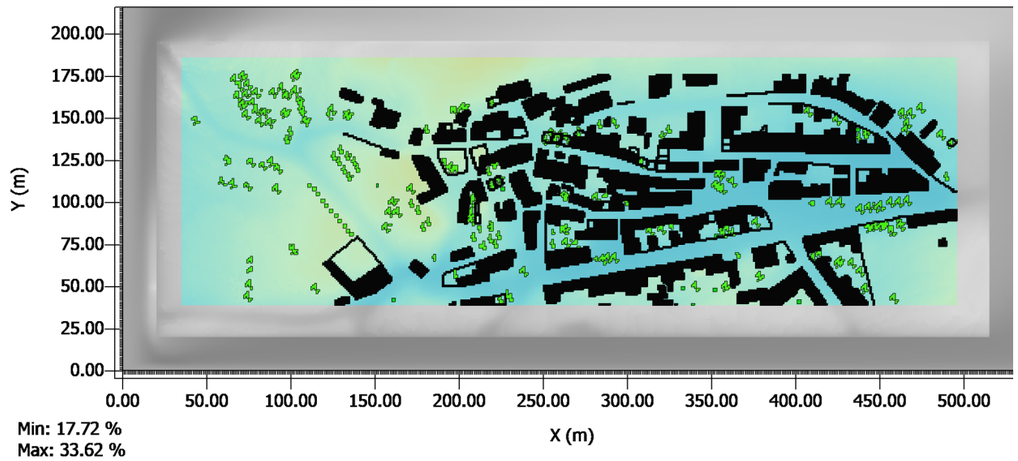
## Summer, 14:00. Relative humidity

2024 model 2024 climate

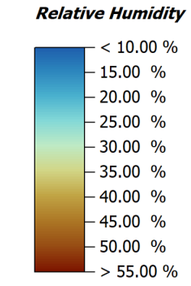



Min: 18.45 %
Max: 38.43 %

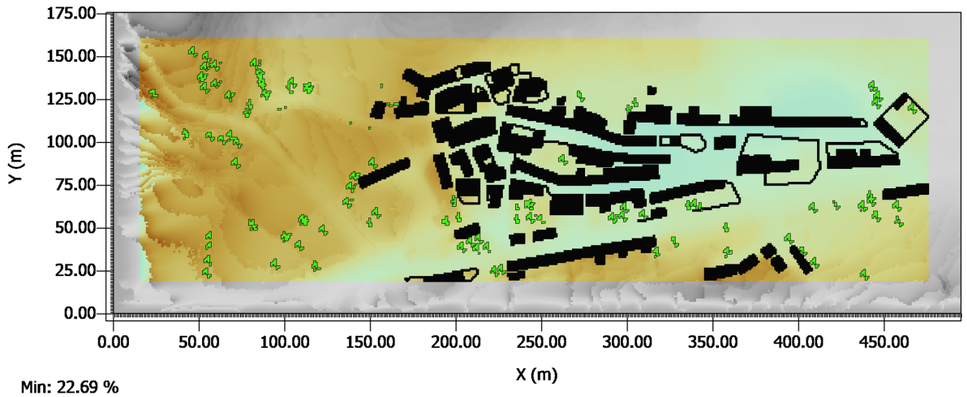
2024 model 1940 climate




Min: 17.72 %
Max: 33.62 %

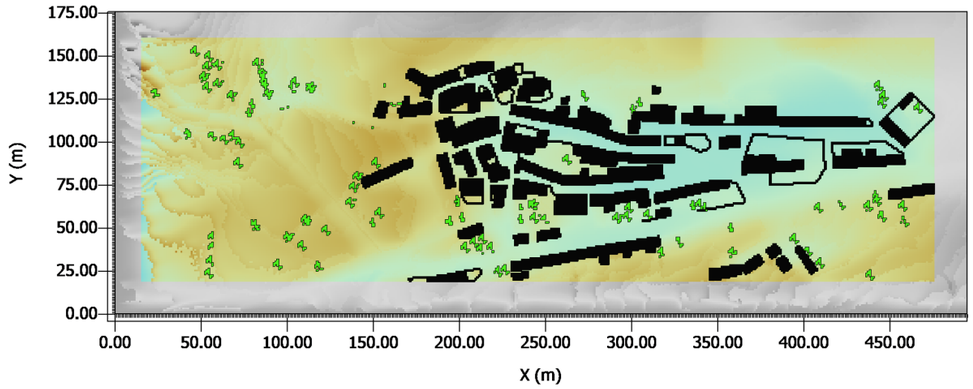



1939 model 2024 climate




Min: 22.69 %
Max: 54.48 %

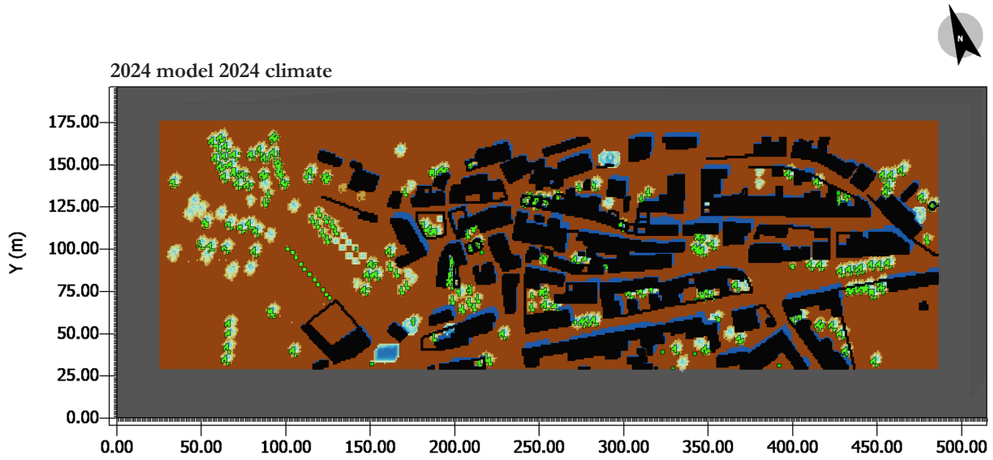
1939 model 1940 climate




Min: 22.16 %
Max: 51.39 %

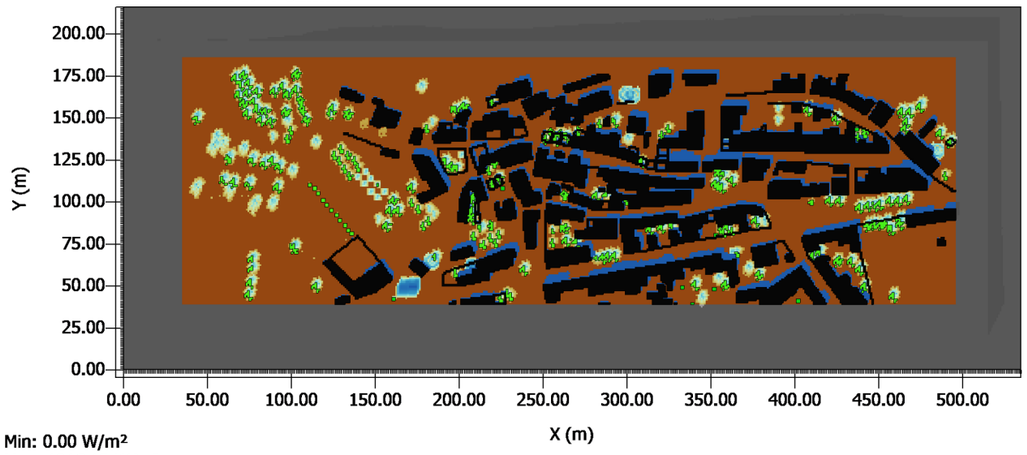
## Summer, 14:00. Direct solar radiation

2024 model 2024 climate

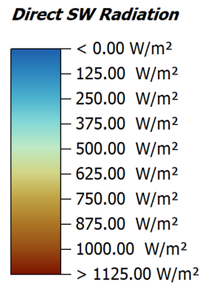



Min: 0.00 W/m²
Max: 1024.83 W/m²

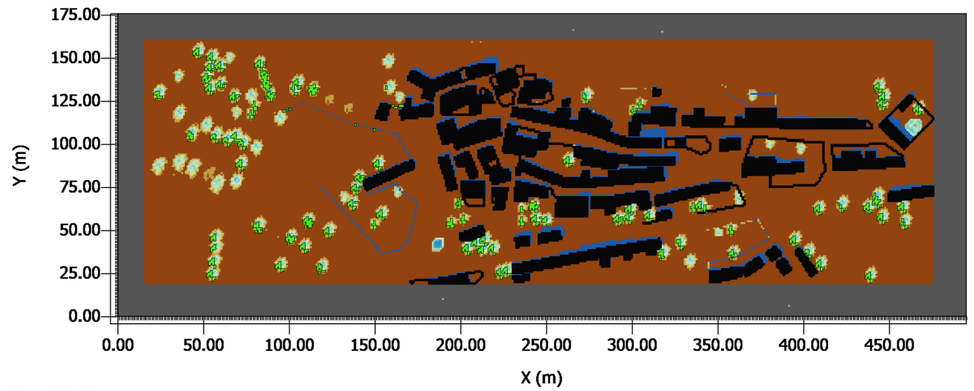
2024 model 1940 climate




Min: 0.00 W/m²
Max: 1016.13 W/m²

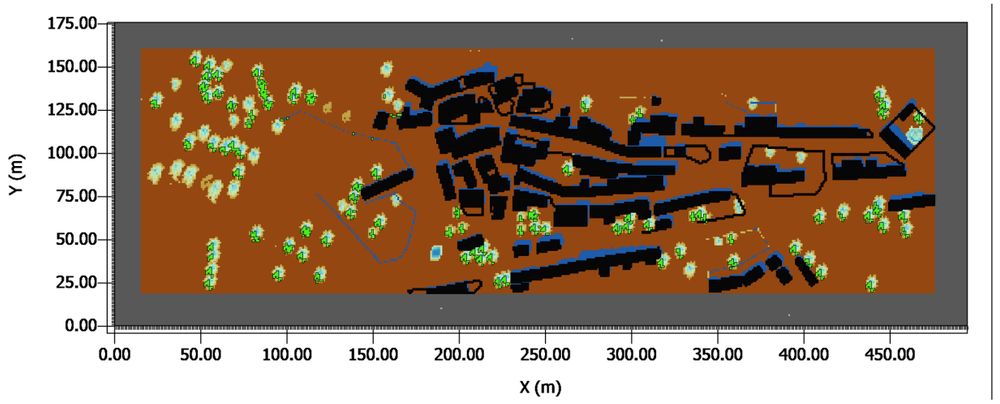



1939 model 2024 climate




Min: 0.00 W/m²
Max: 1024.83 W/m²

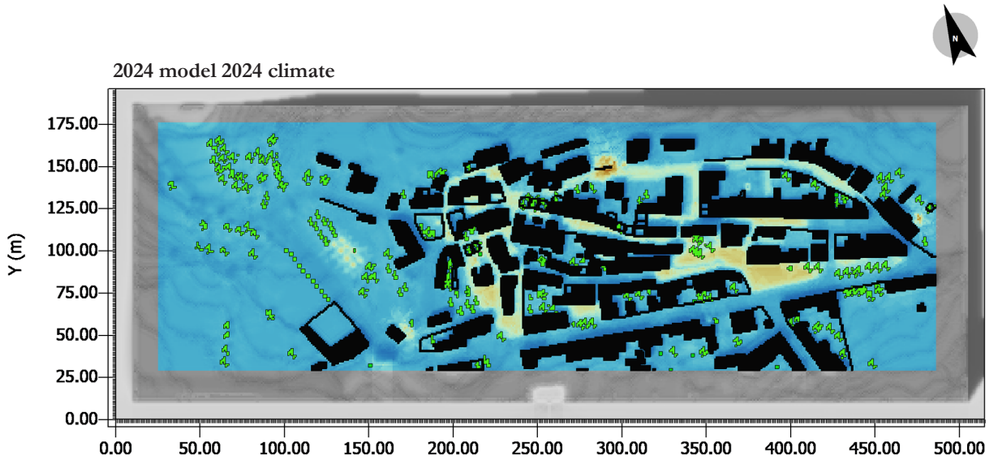
1939 model 1940 climate




Min: 0.00 W/m²
Max: 1016.11 W/m²

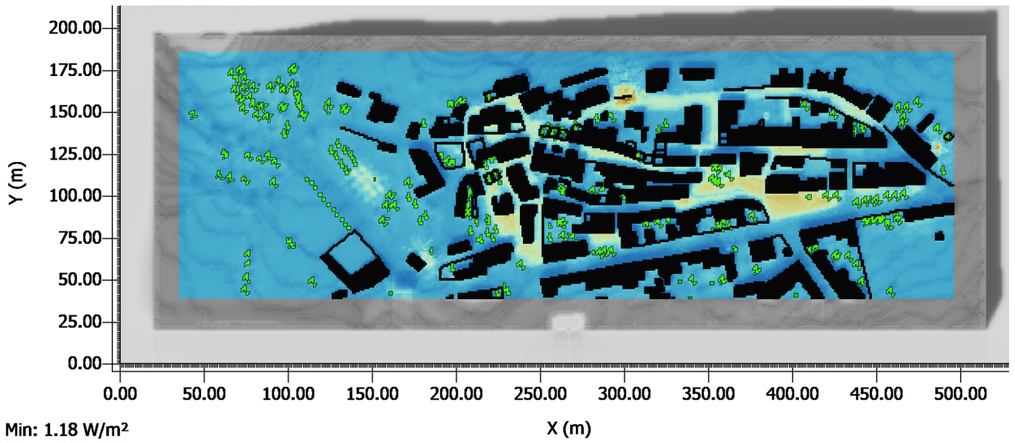
## Summer, 14:00. Reflected solar radiation

2024 model 2024 climate

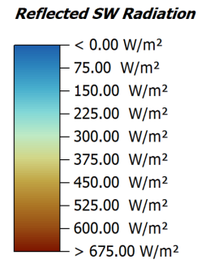



Min: 1.22 W/m²
Max: 630.71 W/m²

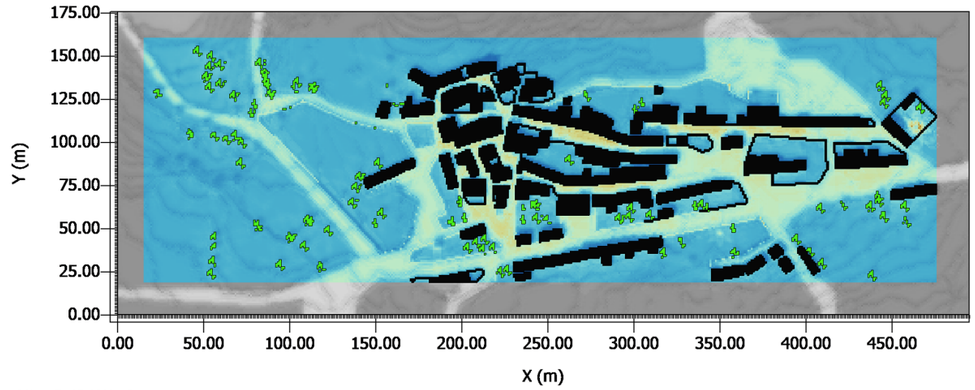
2024 model 1940 climate




Min: 1.18 W/m²
Max: 611.53 W/m²

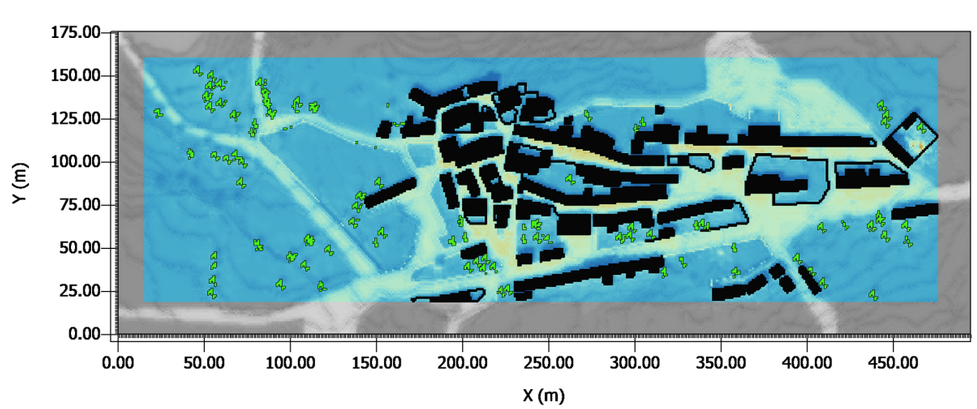



1939 model 2024 climate



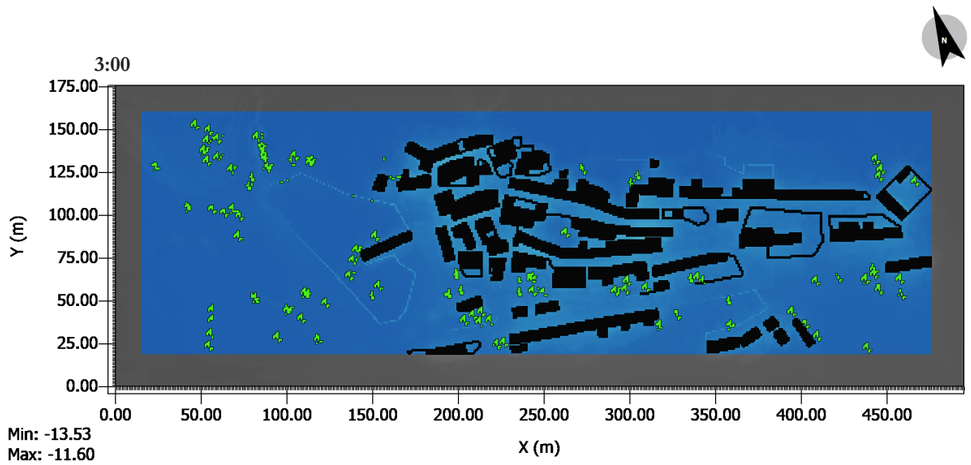

Min: 3.42 W/m²
Max: 506.52 W/m²

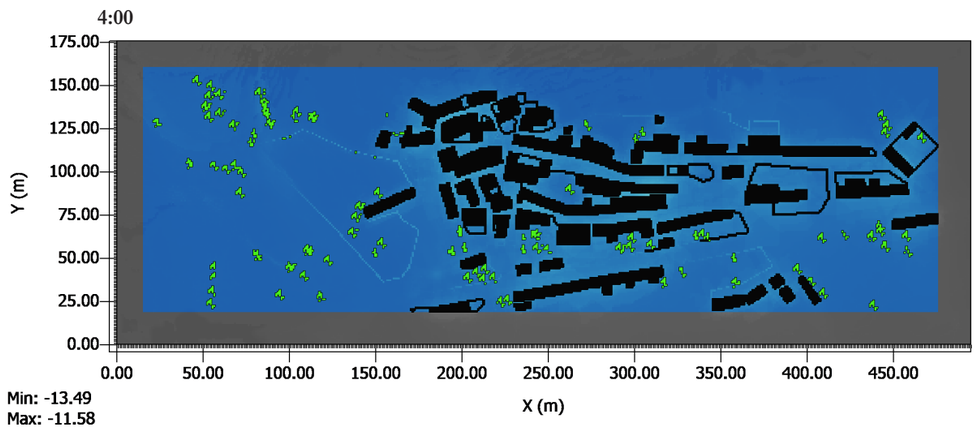
1939 model 1940 climate

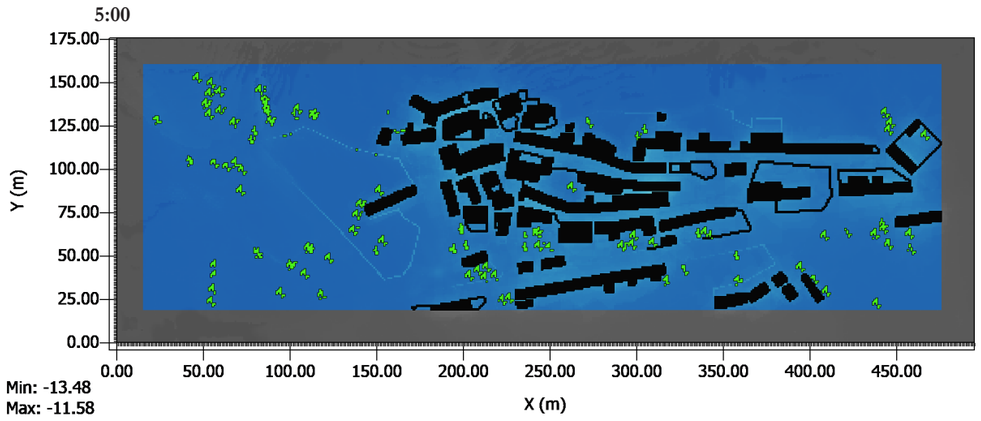


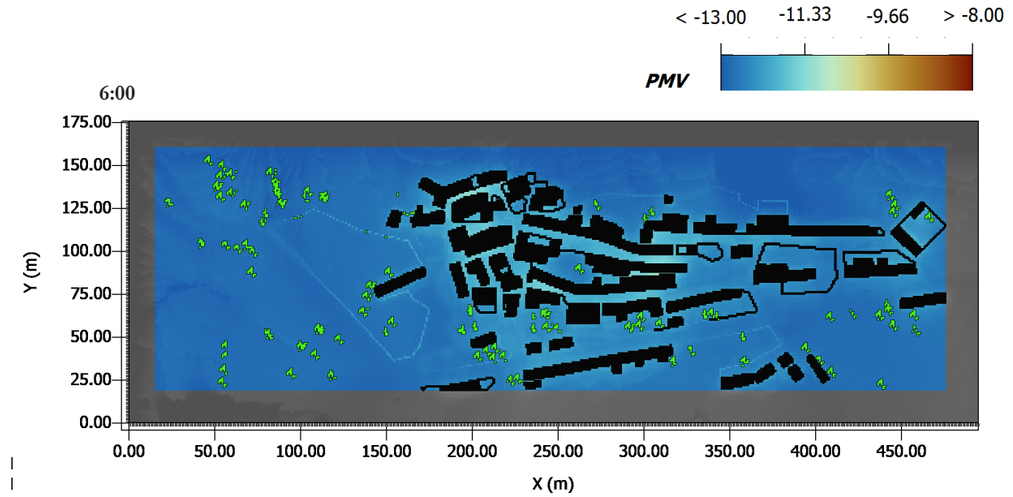

Min: 3.34 W/m²
Max: 487.28 W/m²

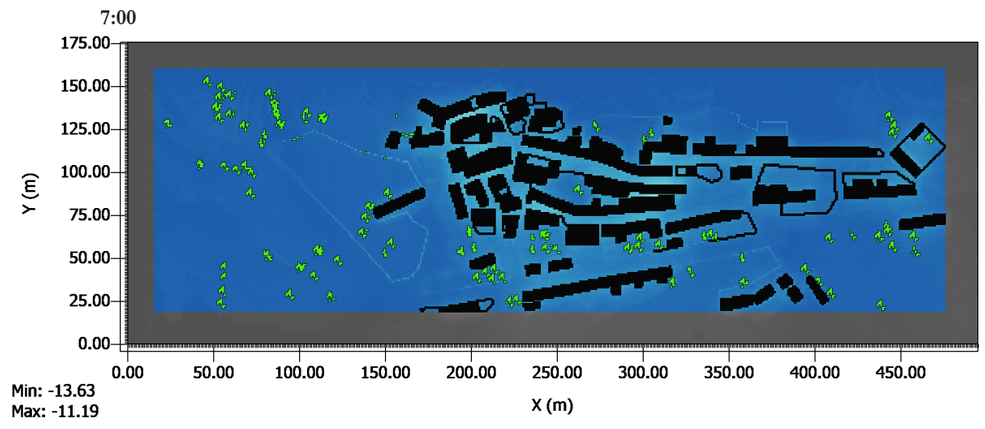
## Winter 1940. PMV

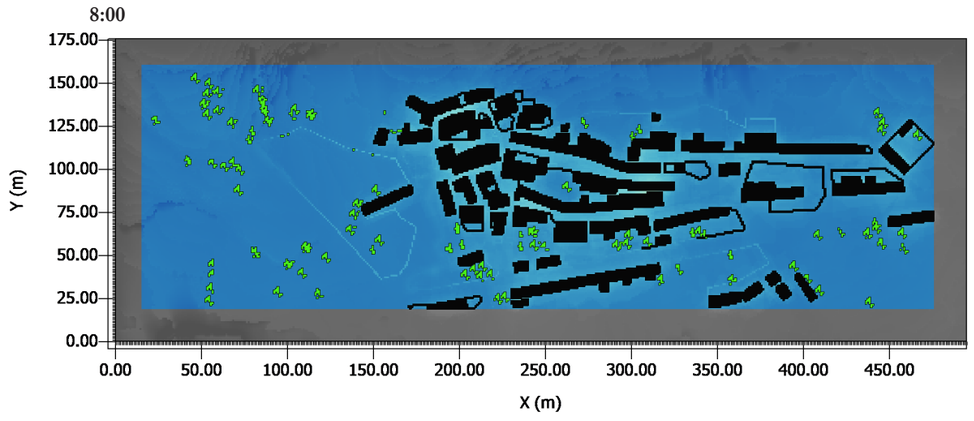


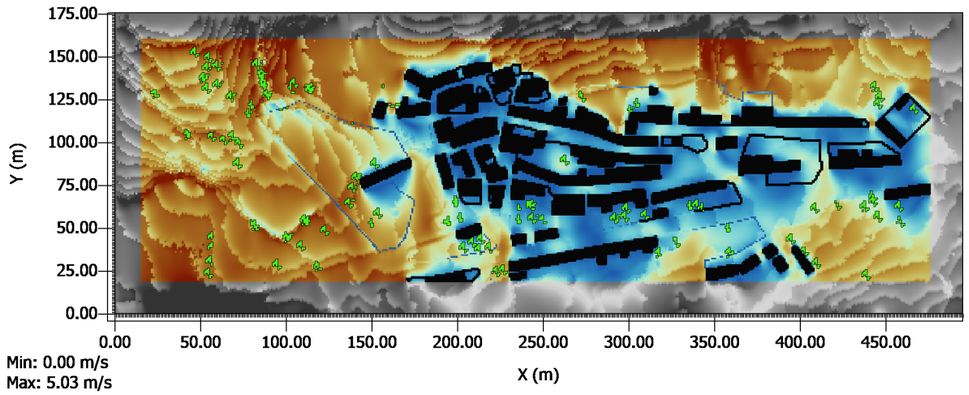



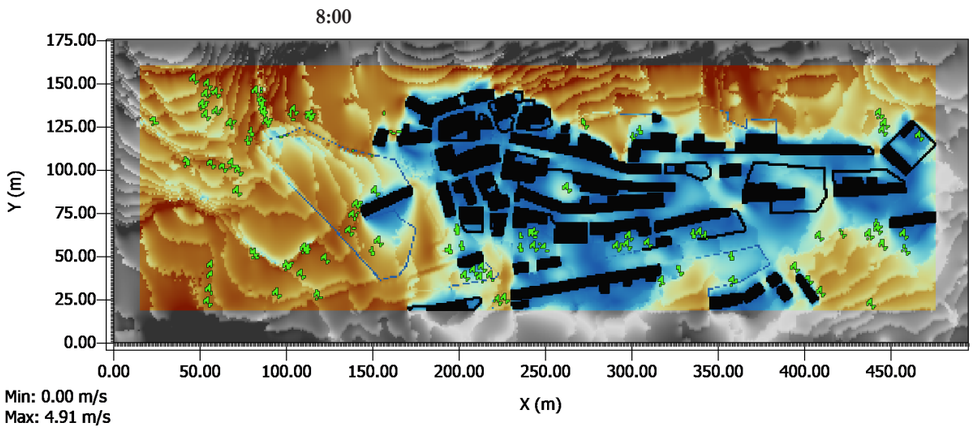



## Winter 1940. Wind speed

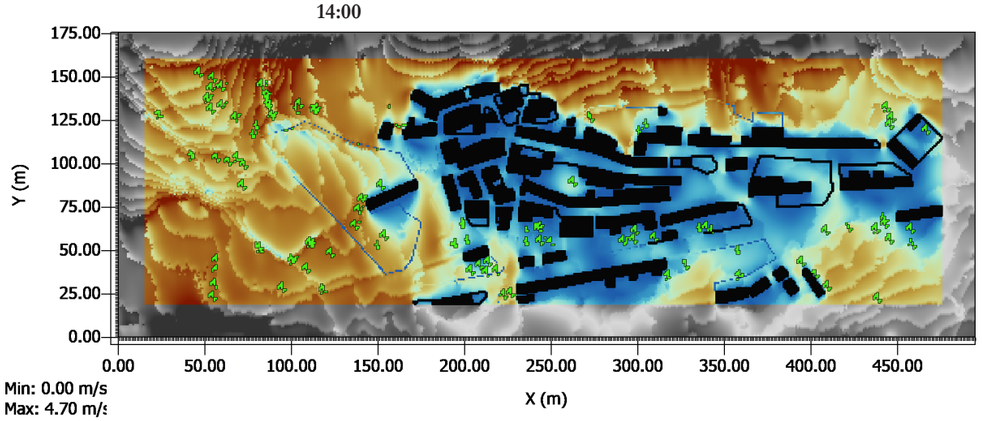
6:00



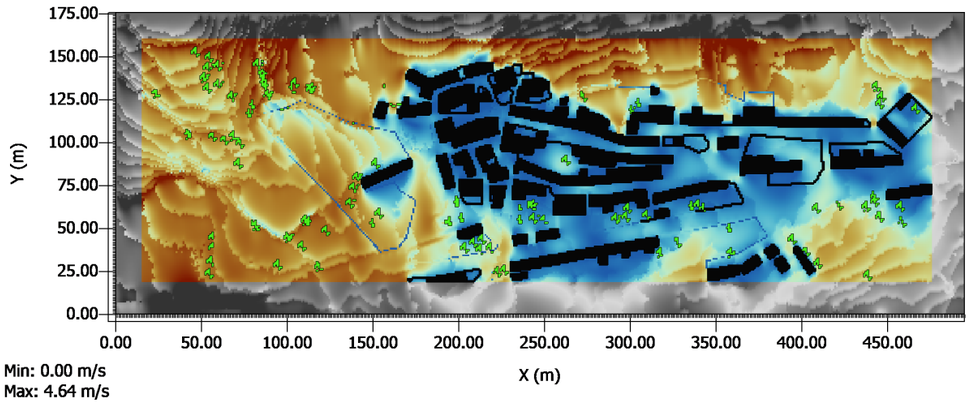

8:00



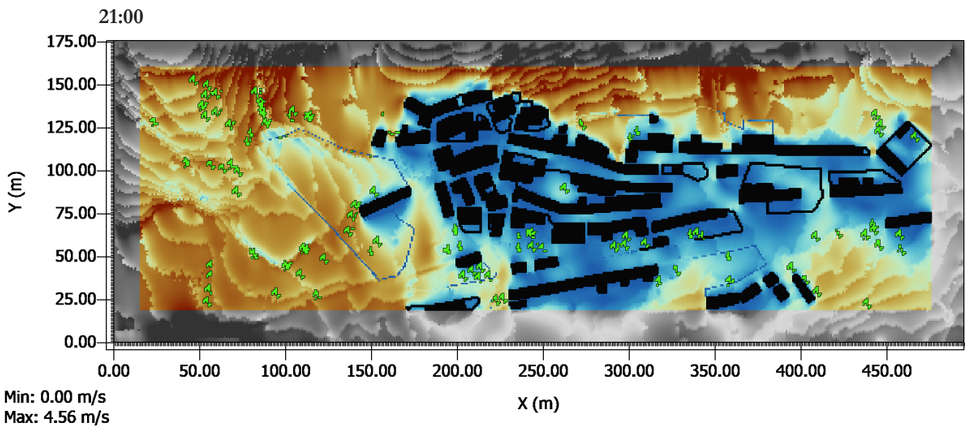

14:00

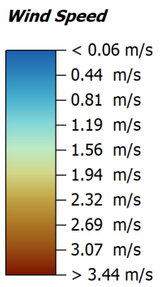



17:00



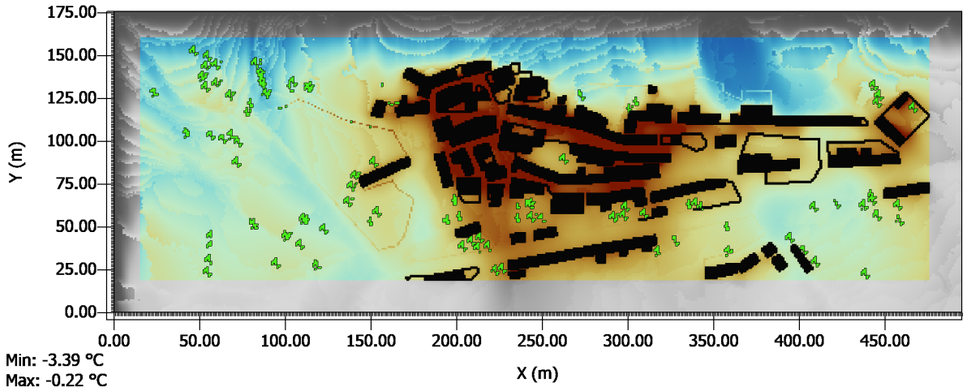

21:00



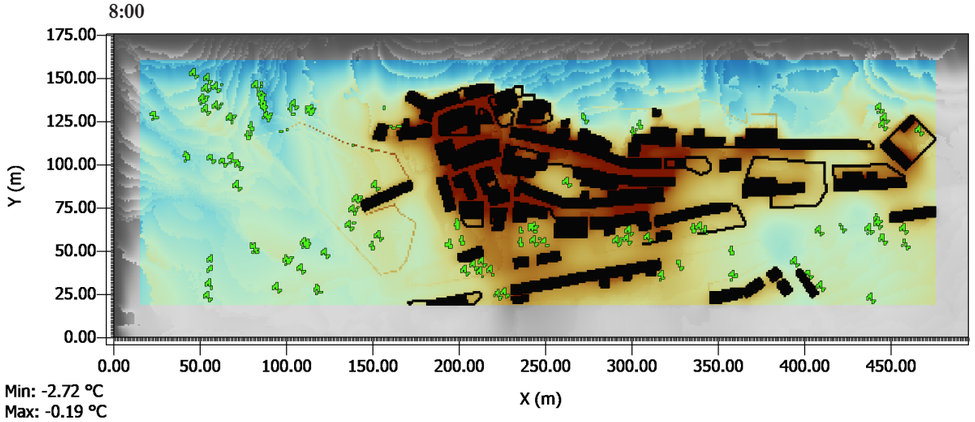



## Winter 1940. Air temperature

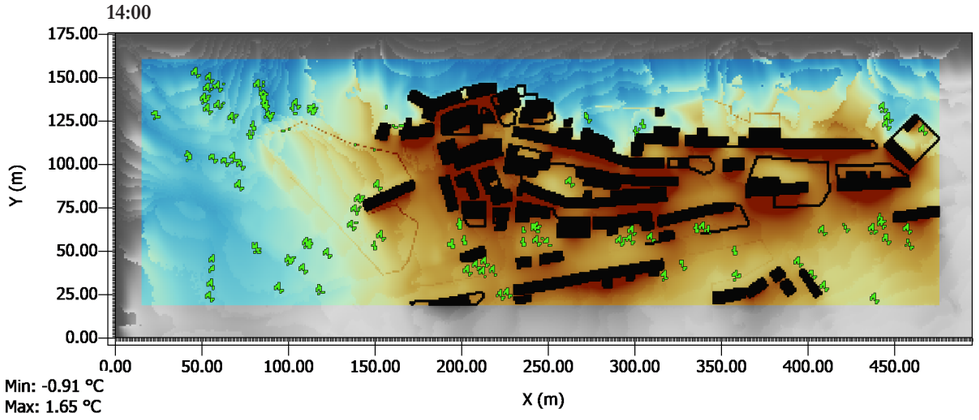
6:00



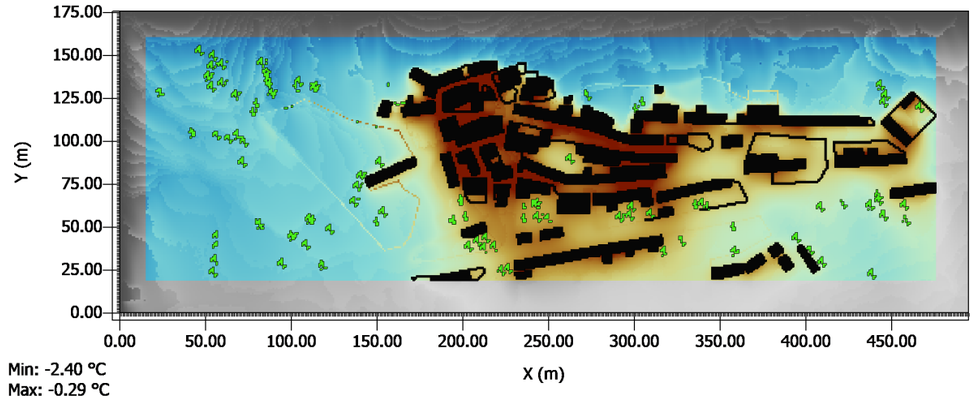

8:00



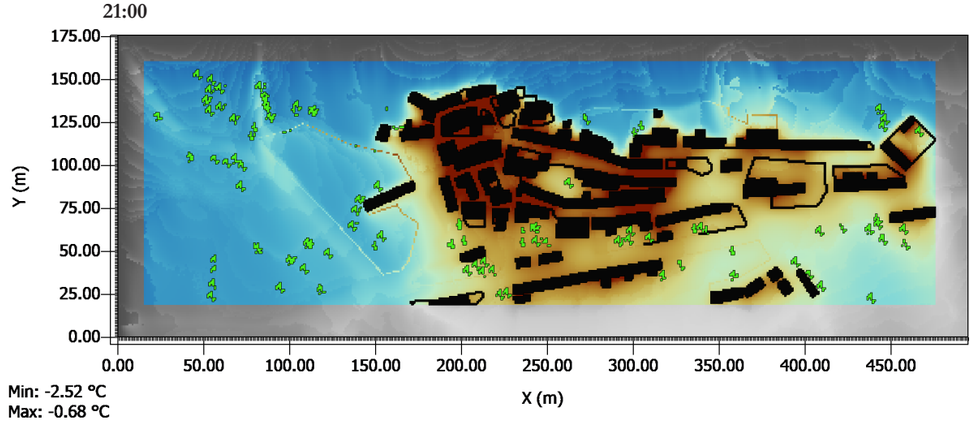

14:00

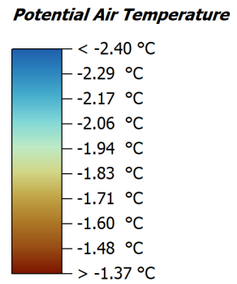



17:00

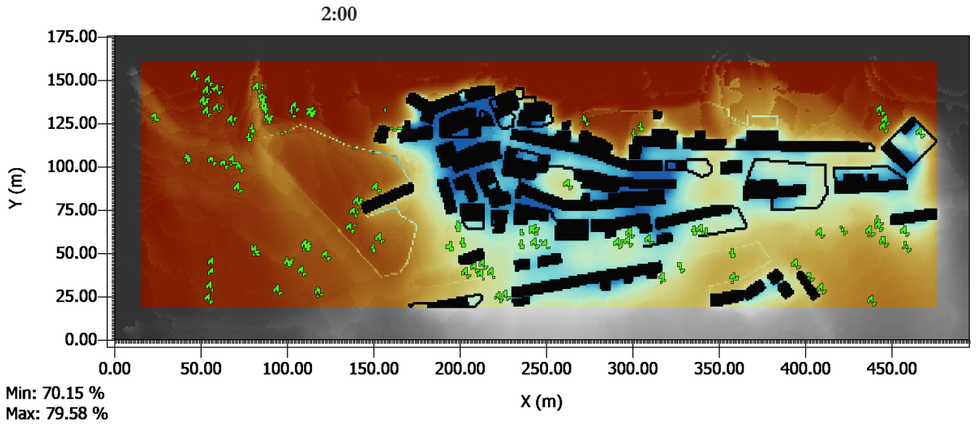



21:00

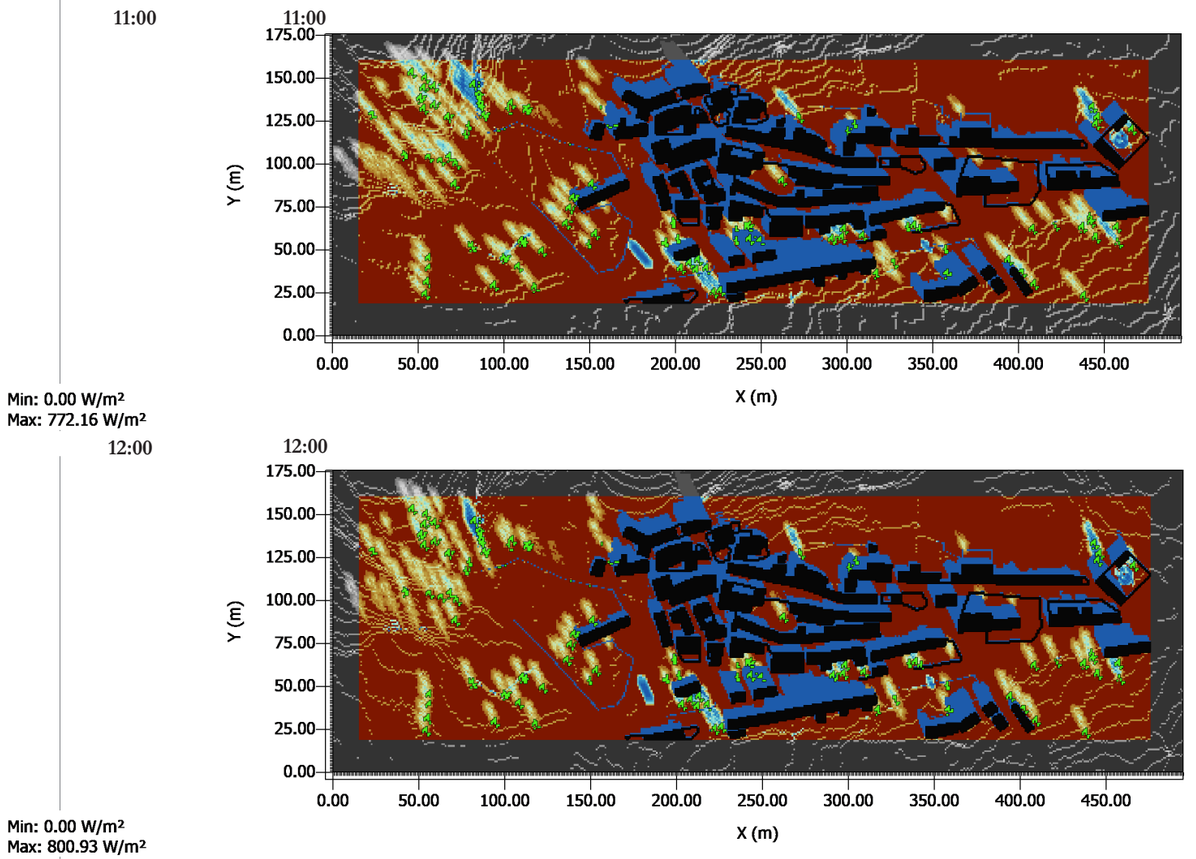


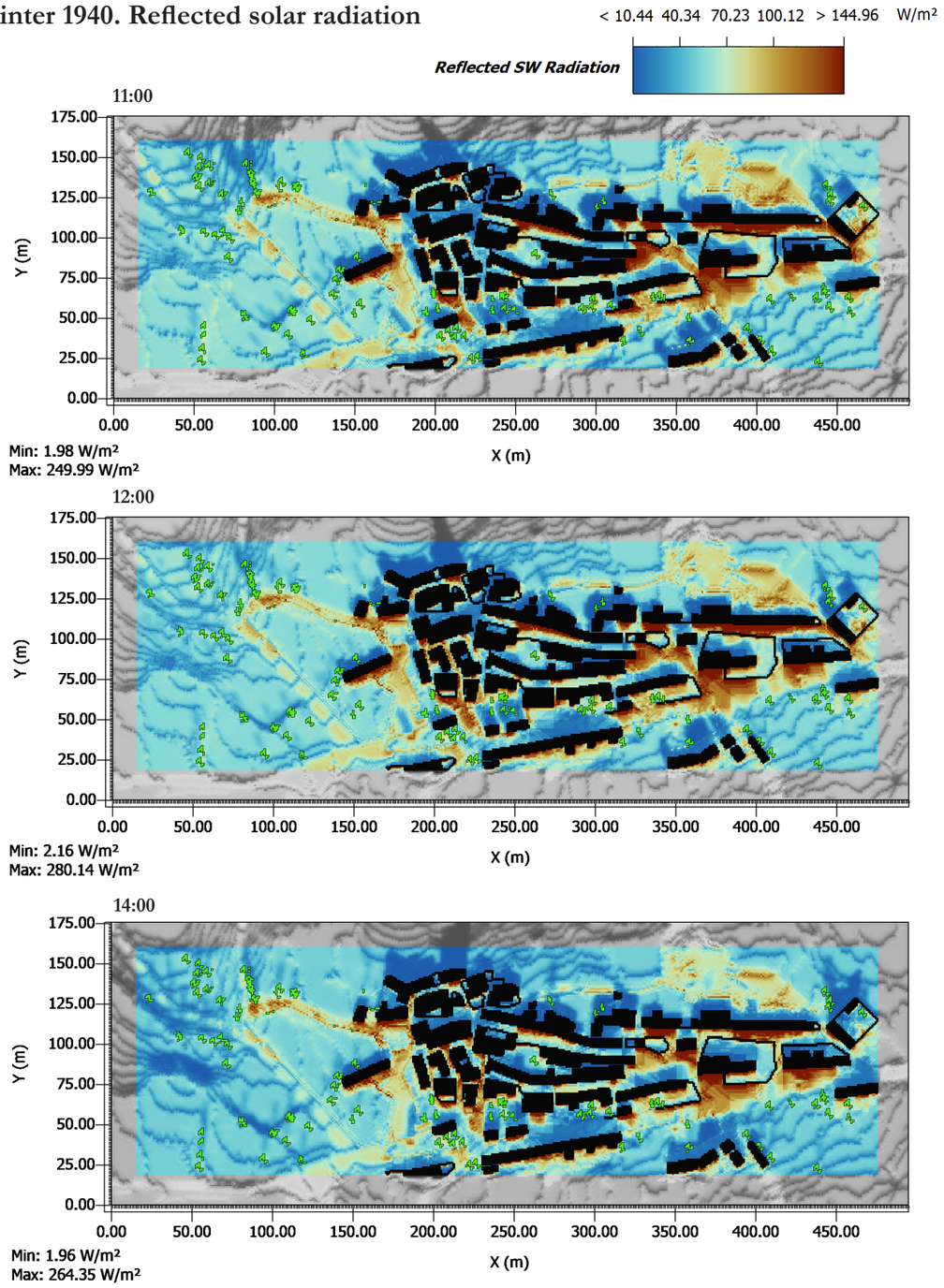
## Winter 1940. Relative humidity




## Winter 1940. Direct solar radiation



## Winter 1940. Reflected solar radiation



# Attachment 5.
# Plaster Parametric Simulations

## Technical sheets for reflective coating

**SPI COATINGS**
PROVEN PERFORMANCE • REAL WORLD SOLUTIONS
**SUPER THERM®**
*INSULATION AND CORROSION SPECIALISTS*

### Technical Data Sheet (09/25/24)

**DESCRIPTION**
SUPER THERM® is a water-borne combination of high-performance aliphatic acrylics, self-crosslinking and resin additives which produces a tough, yet flexible coating film. Designed for performance and durability, SUPER THERM® contains 4 unique ceramics to block heat gain into the surface upon which the coating film is applied. SUPER THERM® resists 95% of Solar heat blocking Visual Light, Ultra Violet (UV), and Infrared (IR). SUPER THERM® is a flexible membrane with low permeability that can greatly reduce expansion and contraction of a roof, and prevents corrosion and surface deterioration.

**TYPICAL USES**
- As a one-coat insulation system on exteriors to block the migration of Solar Heat gain (roofs and side walls).
- Exterior application to reduce or eliminate condensation on HVAC systems, tanks, spheres, storage systems, and concrete walls.
- As a system over metal, concrete, masonry, and wood to resist moisture penetration and corrosion.
- Ability to resist dirt, mold, mildew, and pollution to increase longevity, and reduce surface maintenance.
- As a topcoat over metal roofs, or an intermediate coat on flat roofs.
- Applied over tent fabrics to provide insulation & remain flexible.

**PHYSICAL DATA**
- Solids: By weight 69% / By Volume: 57% (+/-2%)
- 30-60 minutes to tack free at 70°F (21°C)
- Overcoat: 2 hours when 70°F (21°C) at 40% Relative Humidity
- Full Cure: 21 days; dry to touch: 2 hours
- Lead-, chromate-, and asbestos-free
- Cures by evaporation
- Weight: 11.9 lbs. per gallon
- Vehicle Type: Self cross-linking Acrylic blend
- Shelf Life: Up to 5 years if unopened under appropriate storage conditions (See MSDS)—must be stored in areas below 35°C/95°F to avoid drying out in the pail.
- VOC Level: 67.2 grams/liter, 0.561 gal/lbs.
- Viscosity: 105 – 110 KU; 25,000 Centipoise
- pH: 8.5 – 9.5
- 91 sq.ft./gallon (8sqm): 18 mils (450 microns) wet / 10 mils (250 microns) dry
- Maximum Surface Temperature when applying: 150° F (65°C)
- Minimum Surface Temperature when applying: 40°F (5°C)
- Maximum Surface Temperature after curing: 300°F (149°C)
- Do not apply over 18 mils wet per application. Allow to dry down before adding additional thickness.

MEETS MIL SPEC: MIL-PRF-6799L

**APPLICATION METHODS**
SUPER THERM® can be applied to metal, concrete, masonry and wood. The application can be spray, brush or roller. For specific instructions on surface preparation, mixing and application, please refer to the SPI's application instructions for SUPER THERM®. This coating should never be applied at less than 18 mils wet (450 microns), 9.5 mils dry (238 microns), each coat.

NOTE: Do not paint in the rain or if there are or have been heavy cloud conditions or high humidity for a prolonged series of days. Conditions MUST be dry and sunny partly cloudy with enough sun to dry coating film before nightfall.

**TESTS AND CERTIFICATIONS (partial list)**
1. Exterior insulation against Solar Radiation (short/UV/IR)
2. Blocks 99.5% of infrared / up to 68% sound blockage
3. UL (Underwriters Laboratory) approved (quarterly review)
4. Flame Spread Test (ASTM E84; 0 smoke, 0 flame)
5. Class "A" Flame Spread-E108
6. Marine Approvals: - American Bureau of Shipping; USCG
7. UV & Salt Spray Resistance (ASTM 5894) 5000 hours
8. USDA Approved
9. Flexibility (ASTM E1737): 180 degree bend – passed
10. Adhesion ASTM (D4541): 265ps (1.8Mpa) @ 10 dry mils – did not pull off plate. Only intercoat failure.
11. Perm Rating (ASTM D1653-13): 10 dry mils=8perms; 12 dry mils=4perms
12. Abrasion Resistance (ASTM D4060): 3,000 cycles
13. Resistance to Salt Spray: 2,000 hours
14. Resistance to Wind Driven Rain (ASTM D6904)
15. Airforce Canopy: MIL-PRF-6799

**SAFETY PRECAUTIONS**
Do not use this product without first taking all appropriate safety measures to prevent property damage and injuries. These measures may include, without limitation: proper ventilation, use of proper lamps, wearing of protective clothing and masks, tenting, and proper separation of application areas. For more specific safety procedures, please refer to the SUPER THERM® Material Safety Data Sheet. KEEP OUT OF REACH OF CHILDREN.

**********

LIMITATION OF LIABILITY: The information contained in this data sheet is based upon tests that we believe to be accurate and is intended for guidance only. All recommendations or suggestions relating to the use of the products made by SPI, whether in technical documentation, or in response to a specific enquiry, or otherwise, are based on data which to the best of our knowledge is reliable. The products and information are designed for users having the requisite knowledge and industrial skills, and the end-user has the responsibility to determine the suitability of the product for its intended use.

SPI has no control over either the quality of condition of the substrate, or the many factors affecting the use and application of the product. Therefore, SPI does not accept any liability arising from loss, injury, or damage resulting from such use or the contents of this data sheet (unless there are written agreements stating otherwise).

The information contained in this data sheet is subject to modification as a result of practical experience and continuous product development. This data sheet replaces and annuls all previous issues, and the user has the responsibility to ensure that this sheet is current prior to using the product.






### Application Instructions (9/25/24)

*SUPER THERM® is a water-borne combination of high-performance aliphatic self-crosslinking blends, elastomeric acrylics, and resin additives which produces a tough, yet flexible coating film. Designed for performance and durability, SUPER THERM® contains 4 unique ceramics to block up to 95% of Solar Heat entering a structure due to Visual Light, Ultra Violet (UV), and Infrared (IR). SUPER THERM® is a flexible membrane with low permeability that can greatly reduce expansion and contraction of a roof, and prevents corrosion and surface deterioration.*

**SURFACE PREPARATION**
Surface must be clean from oil, tar, rust, grease, salts, and films.
1) Clean surface using TSP (tri-sodium-phosphate) or a citrus cleaner to release dirt and degreaser residue.
2) Pressure-wash, if possible, @ 3500 psi.
3) Salt contamination on the surface can come as a result of salt water, fertilizers, and car exhaust. Use Chlor-Rid or equivalent to decontaminate surface if salts are present. (Acceptable levels: Nitrates: 5-10 mcg/cm², Sulfates: 5-10 mcg/cm², Chlorides: 3-5 mcg/cm²)

**Surface must be completely dry before applying.**
1) SUPER THERM must be applied during proper temperatures (see below) and the prescribed overcoat window of the coating over which it will be applied.
2) Maximum Surface Temperature when applying: 150°F (65°C)
3) Minimum Surface Temperature when applying: 40°F (5°C)
4) Maximum Surface Temperature after curing: 300°F (149°C)

***NOTE:*** Use Rust Grip® as a primer when needed. If pack rust or mill scale exists; it must be removed by grit blast, power tool or zip (no needle gun) gun. Once removed, begin with Step 1 (power wash). Refer to Rust Grip technical data sheet for overcoat window.

***NOTE***: Harsh environments where color is desired, or where pooling may occur: SUPER THERM® should be over-coated with ENAMO GRIP (solvent based) over metal or concrete, and SP SEAL COAT over flexible surfaces (foam, tar, rubber and wood).

***NOTE***: Modified bitumen, asphalt roofing, PVC, TPO and single-ply membranes must be primed with the appropriate primer (i.e. Super Base/HS or SP Single-Ply Primer).

***NOTE***: When applying ENAMO GRIP (solvent) over SUPER THERM when humidity is 60% and temperature is below 38°C (100°F), wait minimum of 24 hours and until SUPER THERM is less than 5-10% moisture content before top coating SUPER THERM to allow evaporation of water.

**MIXING**
SUPER THERM® should be mechanically mixed or mixed by hand (stir stick) for three minutes, then applied.

**APPLICATION**
SUPER THERM® can be applied by brush, roller or spray; however, the preferred method is by air or airless sprayer. It should never be applied directly over rust, nor should it ever be diluted or thinned.
1) If application is by brush, use a soft bristle brush (req. 2 coats).
2) If applied by roller, use a 3/4 inch nap roller (req. 2 coats).
3) If application is by spray, use a standard airless sprayer (2 gallons/minute at 3,300 psi.) with a .029-.033 tip according to fan width spread of application and pump pressure. To achieve proper thickness, temperature and humidity must be considered by applicator. When spraying, overlap each pass by 50% in the next pass.

- ***NOTE*:** The number of applications and the thickness of each should be in accordance with the job specifications.
- ***NOTE:*** All filters should be removed from both the gun handle and spray machine prior to application, as they will trap the ceramics.
- ***NOTE:*** Temperatures must always be a minimum of 5 degrees above the dew point during application.
- ***NOTE:*** If SUPER THERM® is applied during a period of extremely high humidity or if there is rain soon after the application, bubbles may appear on the surface. Do not puncture these bubbles. This is normal and the coating will continue to cure with no effect on the performance or appearance of the coating. Bubbles will dry down tight and disappear without a trace or imprint in following day sun.
- ***NOTE***: 2" corrugation = roof size x 135%; 2.5" corrugation = roof size x 145%; 3" corrugation = roof size x 160%

NOTE: Do not paint in the rain or if there are or have been heavy cloud conditions or high humidity for a prolonged series of days. Conditions **MUST** be dry and sunny or partly cloudy with enough sun to dry coating film before nightfall.

**MINIMUM SPREAD RATES (mil thickness)**
SUPER THERM® will be applied at no less than a total of 18 mils wet (450 microns)/10.0 mils dry (250 microns) for each application. Spread Rate is 91 sq ft per gallon. (8.0 sq meter per gallon)

**CURE TIME**
1) 30-60 minutes to tack free at 70°F (21°C)
2) Overcoat: 2 hours when 70°F (21°C) at 40% Relative Humidity
3) Full Cure: 21 days

**TEMPERATURE**
1) Apply between 40°F. and 150°F.
2) Store between 40°F. and 95°F. (if stored in a hot area, water will need to be added and stirred at time of usage).

**CLEAN-UP EQUIPMENT**
After completion, spray equipment should be cleaned with soap and water; clean brushes and rollers can be reused.

# SAFETY DATA SHEET

pg 1 of 2

## SECTION 1: Identification of the substance

1.1 PRODUCT IDENTIFIER: SUPER THERM (0311)
GHS PRODUCT INDENTIFIED: Global Harmonized System #3209.10.0000
1.2 PRODUCT USE: Insulation coating to create thermal barrier on substrates
1.3 SUPPLIER: SUPERIOR PRODUCTS INT'L II, INC.
10835 W. 78th St., Shawnee, KS 66214 USA
1.4 EMERGENCY TELEPHONE NUMBER: 800-424-9300; 202/483-7616

## SECTION 2: Hazard identification

2.1 Classification of the substance: This products is a water-based coating and is not classified as dangerous for supply or conveyance.

2.2 Label elements: Signal Word: WARNING Hazard Symbol:



Hazard Statement: Irritant, dermal sensitiser, acute toxicity (harmful).
H320 causes eye irritation. H317 may cause an allergic skin reaction.

## SECTION 3: Composition/information on ingredients

3.2

| Ingredient compositions | % | CAS/PIN | Ingredient compositions | % | CAS/PIN |
|---|---|---|---|---|---|
| Fire Retardant | 6.0 | 21645-51-2 | Titanium Dioxide | 6.0 | 13463-67-7 |
| Mica/Additives | 14.0 | 12001-26-2 | Insulator | 24.0 | 93763-70-3 |
| Acrylic Resin | 28.0 | 9003-01-4 | Polyurethane Resin | 12.0 | 58043-05-3 |
| Water | 10.0 | Non-hazmat | | | |

## SECTION 4: First aid measures

4.1 Description of first aid measures
INHALATION: Remove to fresh air.
EYES: Flush w/water for at least 15 minutes; see physician if irritation continues.
SKIN: Wash affected areas w/mild soap & water.
INGESTION: Do not induce vomiting. Give 1-2 glasses milk or water. Seek medical attention according to amount of product ingested.

## SECTION 5: Firefighting measures

5.1 Extinguishing media: Water, water fog, dry chemical, foam or C02
5.2 Special hazards arising from the substance or mixture:
Hazardous combusion products: Carbon monoxide, methacrylate and other noxious gases.
Autoignition Temperature: NAP Minimum ignitions energy: NAV
Flash point: NAP Flammable limits: (Lower) NAP / (Upper): NAV%
Sensitivity to static discharge? NO Sensitivity to mechanical impact? NO
Conditions of flammabillity: Not flammable; water-based product
5.3 Advice for firefighters: Firefighters should wear full-body protection & SCBA

## SECTION 6: Accidental release measures

6.1 Personal precautions: Use protective clothing; use particulate respirator when spraying.
6.3 Methods of cleanup: Use kitty litter or similar absorbent to contain spill.

## SECTION 7: Handling and storage

7.1 Precautions for safe handling: Treat as paint product. Use ventilation and protective equipment to suit conditions of use.
7.2 Conditions for safe storage: Keep from freezing. Store below 50C degrees. Keep container closed tightly to prevent drying out.

PRODUCT IDENTIFIER: **SUPER THERM**

pg 2 of 2

## SECTION 8: Exposure Controls/personal protection

8.1 Control parameters: Avoid inhalation of liquid when applying. Use particulate respirator.
ENGINEERING CONTROLS: Use mechanical exhaust ventilation to control aerosol or mist if sprayed.

## SECTION 9: Physical and Chemical Properties

9.1 Information on basic physical and chemical properties:
PHYSICAL STATE: Liquid SOLUBILITY IN WATER: Soluable pH: 8
APPEARANCE AND ODOR: White, mild acrylic odor FREEZING POINT: 30F degrees
BOILING POINT: >192C. deg. SPECIFIC GRAVITY: 1.4 ODOR THRESHOLD: 0.8-25ppm
COEFF. WATER/OIL: NAV EVAPORATION RATE: slow% VOLATILES: <5
VAPOUR DENSITY (Air=1): NAV VAPOUR PRESSURE: 18mmHg@20C. deg. CORROSIVE: NO

## SECTION 10: Stability and reactivity

10.1 Conditions of Reactivity: Stable
10.2 Conditions of Instability: Stable under normal conditions
10.3 Possibility of hazardous reactions: None known.
10.4 Conditions to avoid: None known.
10.5 Incompatible materials: Strong acids or bases
10.6 Hazardous decomposition products: None known, no hazardous polymerization

## SECTION 11: Toxicology Information

11.1 Information on toxicological effects:
Acute toxicity - oral: Not meant to be ingested; no known significant effects or critical hazards
Acute toxicity - inhalation: Vapors or mist can cause mild irritation.
Acute toxicity - dermal: Liquid splash could result in eye or nose irritations and/or headach
Health effects to chronic exposure: Excessive exposure to liquid product may result in minor irritations

## SECTION 12: Ecological Information

12.1 Toxicity
No known toxins as product is water-based and not deemed hazardous.

## SECTION 13: Disposal considerations

13.1 Waste treatment methods: Dispose of as paint according to local regulations.

## SECTION 14: Transport information

This product is not regulated in any capacity of transport.

## SECTION 15: Regulatory information

15.1 Safety, health and environmental regulations/legislation specific for the substance: No listed materials under Superfund Amendments & Reauthorization Act of 1988 (SARA) 302, 304, 311, 312. Meets European codes under Article 59(10) of the Reach regulation.

## SECTION 16: Other information

**PREPARED BY:** J. Pritchett, Superior Products Int'l II, Inc. **DATE**: 6/2/23

TPRL 1780

Thermophysical Properties of SUPER THERM Coating

A Report to Superior Products International II, Inc.

by

H. Groot, J. Ferrier and D.L. Taylor

January 1997



TABLE 1

Sample Dimensions, Masses and Density Values

| Sample (No.) | Thickness (cm) | Width (cm) | Length (cm) | Mass (gm) | Density ($gms\ cm^{-3}$) |
|---|---|---|---|---|---|
| 1 | 0.0844 | 1.2800 | 1.2862 | 1.07509 | 7.737 |
| 2 | 0.0843 | 1.2824 | 1.2858 | 1.07928 | 7.764 |
| 3 | 0.0844 | 1.2773 | 1.2826 | 1.07056 | 7.743 |
| 4 | 0.0841 | 1.2802 | 1.2814 | 1.06969 | 7.754 |
| 5 | 0.0844 | 1.2785 | 1.2824 | 1.07005 | 7.733 |
| 1+PAINT | 0.0149 | 1.2800 | 1.2862 | 0.03819 | 1.556 |
| 2+PAINT | 0.0397 | 1.2824 | 1.2858 | 0.11217 | 1.716 |
| 3+PAINT | 0.0474 | 1.2773 | 1.2826 | 0.12874 | 1.657 |
| 4+PAINT F | 0.0211 | 1.2802 | 1.2814 | 0.05740 | 1.661 |
| 4+PAINT FB | 0.0411 | 1.2802 | 1.2814 | 0.10808 | 1.603 |

TABLE 2

Specific Heat Results

| Temperature (C) | Specific Heat (W-s/gm-K) Paint | Specific Heat (W-s/gm-K) Plate |
|---|---|---|
| 23.0 | 1.1861 | 0.4407 |
| 30.0 | 1.2110 | 0.4474 |
| 40.0 | 1.2400 | 0.4561 |
| 50.0 | 1.2661 | 0.4638 |
| 60.0 | 1.2870 | 0.4707 |
| 70.0 | 1.3111 | 0.4770 |
| 80.0 | 1.3305 | 0.4828 |
| 90.0 | 1.3540 | 0.4906 |
| 100.0 | 1.3695 | 0.4951 |

TABLE 3

Thermal Diffusivity Results

| Temperature (C) | Plate ($cm^2\ sec^{-1}$) | t=0.0149 cm ($cm^2\ sec^{-1}$) | t=0.0397 cm ($cm^2\ sec^{-1}$) | t=0.0474 cm ($cm^2\ sec^{-1}$) |
|---|---|---|---|---|
| 23.0 | 0.14800 | 0.00279 | 0.00324 | 0.00324 |
| 50.0 | 0.14700 | 0.00272 | 0.00303 | 0.00311 |
| 75.0 | 0.14200 | 0.00271 | 0.00287 | 0.00300 |
| 100.0 | 0.13800 | 0.00256 | 0.00274 | 0.00285 |

TABLE 4

Thermal Conductivity Calculations

| Sample (No.) | Temp. (C) | Density ($gm\ cm^{-3}$) | Specific Heat ($W\text{-}s\text{-}gm^{-1}K^{-1}$) | Diffusivity ($cm^2\ sec^{-1}$) | Conduct. ($W\text{-}cm^{-1}\ K^{-1}$) | Conduct. (BTU *) | Temp (F) |
|---|---|---|---|---|---|---|---|
| Plate | 23.0 | 7.746 | 0.4407 | 0.14800 | 0.50523 | 350.54 | 73.4 |
| | 50.0 | 7.746 | 0.4638 | 0.14700 | 0.52808 | 366.39 | 122.0 |
| | 75.0 | 7.746 | 0.4800 | 0.14200 | 0.52796 | 366.30 | 167.0 |
| | 100.0 | 7.746 | 0.4951 | 0.13800 | 0.52925 | 367.20 | 212.0 |

* (BTU in $hr^{-1}\ ft^{-2}\ F^{-1}$)



TABLE 5

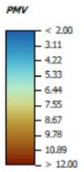
Thermal Conductivity Calculations

| Sample (No.) | Temp. (C) | Density ($gm\ cm^{-3}$) | Specific Heat ($W\text{-}s\text{-}gm^{-1}K^{-1}$) | Diffusivity ($cm^2\ sec^{-1}$) | Conduct. ($W\text{-}cm^{-1}\ K^{-1}$) | Conduct. (BTU *) | Temp (F) |
|---|---|---|---|---|---|---|---|
| t=0.0149 | 23.0 | 1.639 | 1.1871 | 0.00279 | 0.00543 | 3.77 | 73.4 |
| | 50.0 | 1.639 | 1.2657 | 0.00272 | 0.00564 | 3.92 | 122.0 |
| | 75.0 | 1.639 | 1.3211 | 0.00271 | 0.00587 | 4.07 | 167.0 |
| | 100.0 | 1.639 | 1.3695 | 0.00256 | 0.00575 | 3.99 | 212.0 |
| t=0.0397 | 23.0 | 1.639 | 1.1871 | 0.00324 | 0.00630 | 4.37 | 73.4 |
| | 50.0 | 1.639 | 1.2657 | 0.00303 | 0.00629 | 4.36 | 122.0 |
| | 75.0 | 1.639 | 1.3211 | 0.00287 | 0.00621 | 4.31 | 167.0 |
| | 100.0 | 1.639 | 1.3695 | 0.00274 | 0.00615 | 4.27 | 212.0 |
| t=0.0474 | 23.0 | 1.639 | 1.1871 | 0.00324 | 0.00630 | 4.37 | 73.4 |
| | 50.0 | 1.639 | 1.2657 | 0.00311 | 0.00645 | 4.48 | 122.0 |
| | 75.0 | 1.639 | 1.3211 | 0.00300 | 0.00650 | 4.51 | 167.0 |
| | 100.0 | 1.639 | 1.3695 | 0.00285 | 0.00640 | 4.44 | 212.0 |

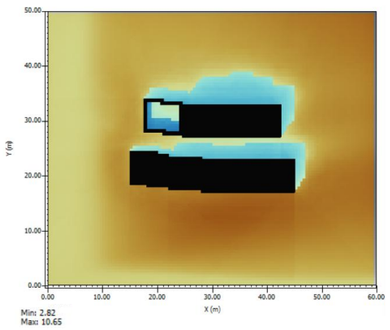
* (BTU in $hr^{-1}\ ft^{-2}\ F^{-1}$)

* (BTU in $hr^{-1}\ ft^{-2}\ F^{-1}$)

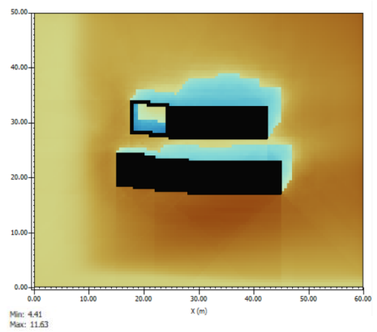
## Plaster parametric simulations, Summer 2024, 14:00. PMV



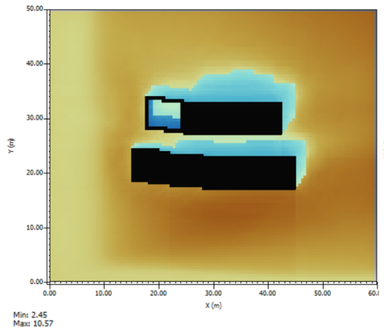

Bare granite wall



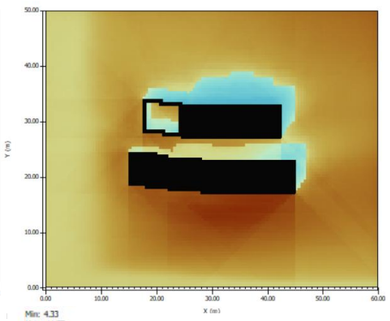

Lime plaster



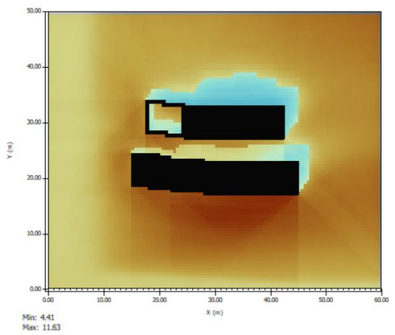

Cement plaster




Cement plaster + Reflective coating




Lime plaster + Reflective coating




| | Bare Granite | Limestone Plaster | Cement Plaster | Reflective Material with Limestone Plaster Base | Reflective Material with Cement Plaster Base |
|---|---|---|---|---|---|
| **Min** | 2.82 [-] | 3.15 [-] | **2.45** [-] | 4.41 [-] | 4.33 [-] |
| **Max** | 10.65 [-] | 11.01 [-] | **10.57** [-] | 11.63 [-] | 11.57 [-] |

## Changes in hourly PMV values in the five models

| **Bare Granite** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 2.90 | 4.45 | 6.05 | 7.40 | 9.41 | 10.45 | 10.71 | 10.65 | 10.24 | 9.43 | 8.32 |

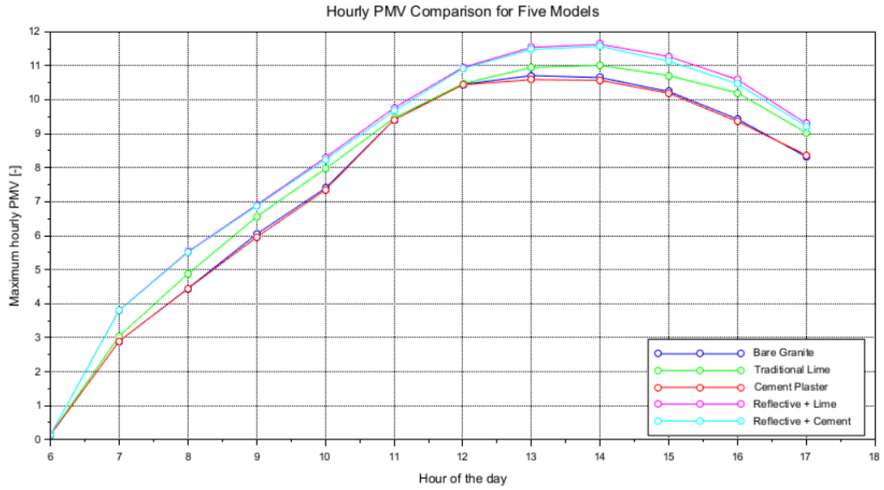
| **Traditional Lime** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 3.05 | 4.88 | 6.56 | 7.97 | 9.46 | 10.47 | 10.95 | 11.01 | 10.71 | 10.20 | 9.03 |

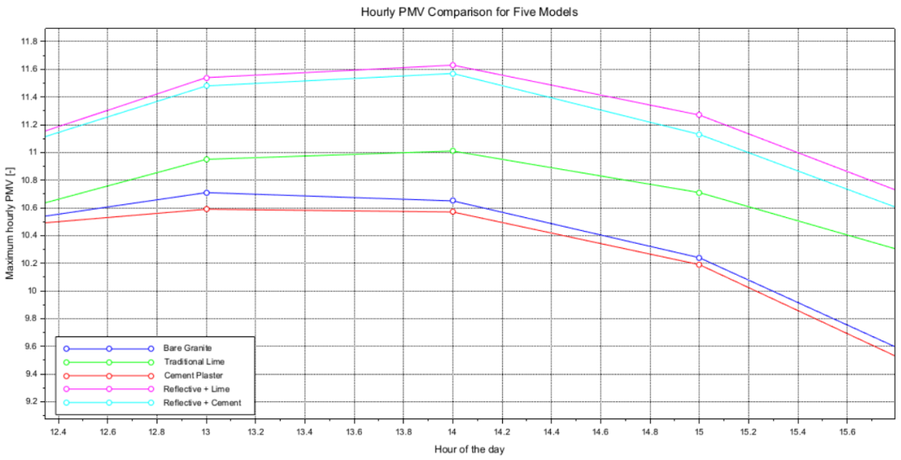
| **Cement Plaster** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 2.90 | 4.44 | 5.96 | 7.35 | 9.41 | 10.44 | 10.59 | 10.57 | 10.19 | 9.36 | 8.37 |

| **Reflective Material + Lime Base** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 3.81 | 5.53 | 6.91 | 8.30 | 9.76 | 10.95 | 11.54 | 11.63 | 11.27 | 10.59 | 9.30 |

| **Reflective Material + Cement Base** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hour of a day [h] | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Max PMV [-] | 0.15 | 3.80 | 5.51 | 6.88 | 8.24 | 9.67 | 10.92 | 11.48 | 11.57 | 11.13 | 10.47 | 9.22 |

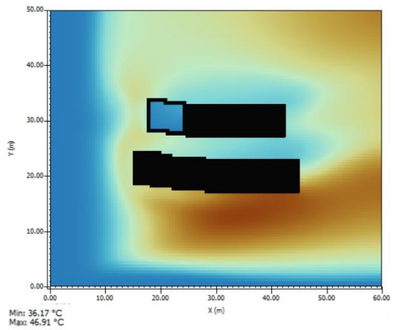
## Comparison of max PMV values and zoom of PMV values at the peak point



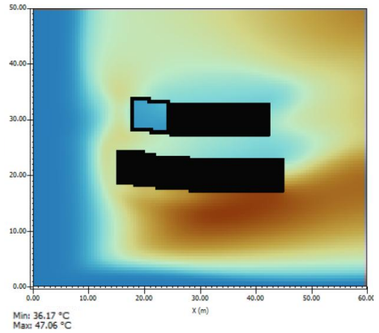



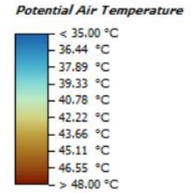

## Plaster parametric simulations, 2024, 14:00. Air temperature

Bare granite wall

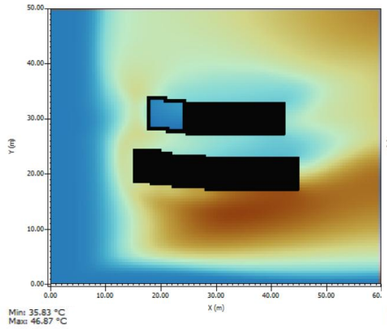



Lime plaster

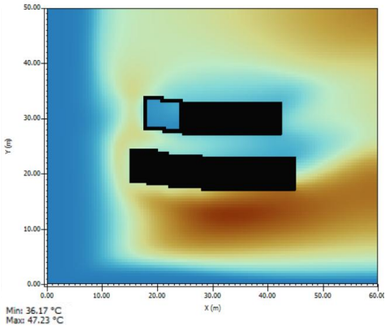


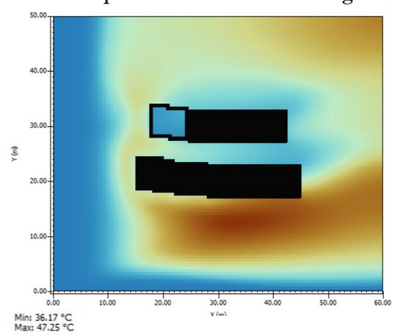

Cement plaster




Cement plaster + Reflective coating

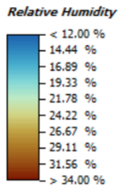



Lime plaster + Reflective coating

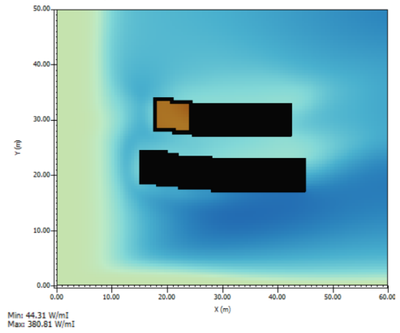



| | Bare Granite | Limestone Plaster | Cement Plaster | Reflective Material with Limestone Plaster Base | Reflective Material with Limestone Plaster Base |
|---|---|---|---|---|---|
| **Min** | 36.17 °C | 36.17 °C | **35.83 °C** | 36.17 °C | 36.17 °C |
| **Max** | 46.91 °C | 47.06 °C | 46.87 °C | **47.25 °C** | **47.23 °C** |

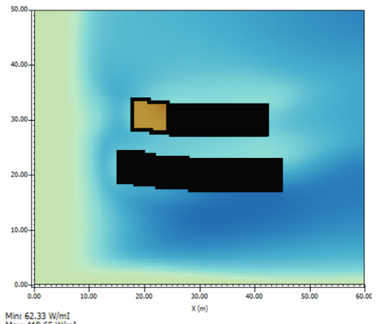
## Plaster parametric simulations, 2024, 14:00. Air temperature



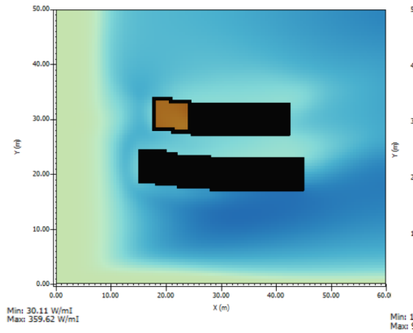

Bare granite wall



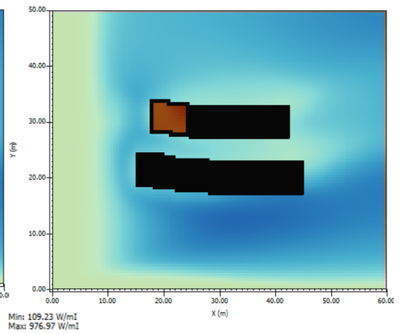

Lime plaster



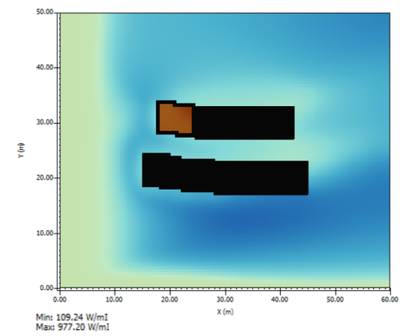

Cement plaster




Cement plaster + Reflective coating



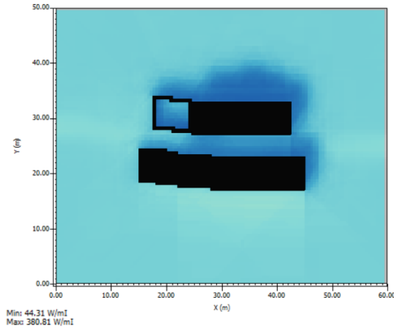

Lime plaster + Reflective coating



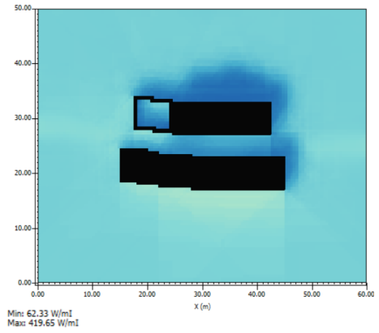

| | Bare Granite | Limestone Plaster | Cement Plaster | Reflective Material with Limestone Plaster Base | Reflective Material with Cement Plaster Base |
|---|---|---|---|---|---|
| **Min** | 13.00% | 12.91% | 13.03% | **12.78%** | 12.79% |
| **Max** | 30.65% | 28.99% | 30.47% | 32.69% | **33.46%** |

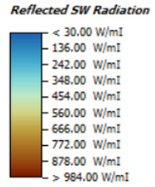
## Plaster parametric simulations, 2024, 14:00. Reflected Radiation

Bare granite wall

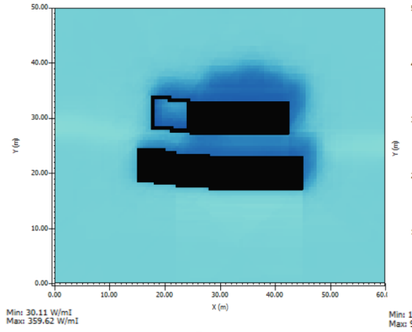



Lime plaster

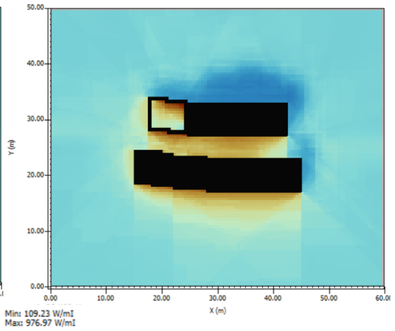


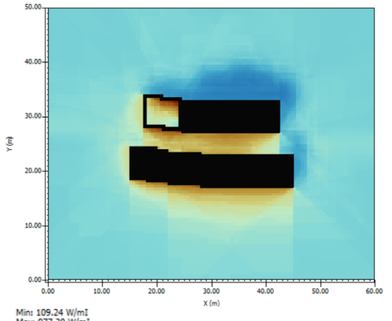

Cement plaster




Cement plaster + Reflective coating




Lime plaster + Reflective coating




| | Bare Granite | Limestone Plaster | Cement Plaster | Reflective Material with Limestone Plaster Base | Reflective Material with Cement Plaster Base |
|---|---|---|---|---|---|
| **Min** | 44.31 $W/m^2$ | 62.33 $W/m^2$ | **30.11 $W/m^2$** | **109.24 $W/m^2$** | 109.23 $W/m^2$ |
| **Max** | 380.81 $W/m^2$ | 419.65 $W/m^2$ | **359.62 $W/m^2$** | **977.20 $W/m^2$** | 976.97 $W/m^2$ |

# Attachment 6.
# Computational Parameters and Time of the Simulations

| Model domain | Climatic conditions | Simulated day | Urban form | Dimension of cells | Dimension of the 3D domain | Number of cells in the model | Modelling and computational time (developing, testing, and validation) (number of days) | Computational time (hours) | Computational time (days) |
|---|---|---|---|---|---|---|---|---|---|
| Entire settlement | Summer 1940 | 06/08/1940 | 1939 | 1m x 1m x 1m | 495m x 176m x 91,5m | 495 x 176 x 64 = 5.575.680 | 70 | 325h 37min 59s | 13,5 |
| Entire settlement | Summer 2024 | 12/07/2024 | 2024 | 1m x 1m x 1m | 515m x 196m x 91,5 m | 515 x 196 x 64 = 6.460.160 | 100 | 357h 45min 6s | 15 |
| Entire settlement | Summer 1940 | 06/08/1940 | 2024 | 1m x 1m x 1m | 535m x 216m x 91,5m | 535 x 216 x 64 = 7.395.840 | 30 | 325h 37min 59s | 13,5 |
| Entire settlement | Summer 2024 | 12/07/2024 | 1939 | 1m x 1m x 1m | 495m x 176m x 91,5m | 495 x 176 x 64 = 5.575.680 | 30 | 325h 27min 2s | 13,5 |
| Entire settlement | Winter 1940 | 18/12/1940 | 1939 | 1m x 1m x 1m | 495m x 176m x 91,5m | 496 x 176 x 64 = 5.575.680 | 40 | 408h | 17 |
| Parametric detailed model (bare walls) | Summer 2024 | 12/07/2024 | 2024 | 0,5m x 0,5m x 0,5m | 60m x 50m x 32m | 120 x 100 x 64 = 192.000 | 60 | 20h | < 1 |
| Parametric detailed model (lime plaster) | Summer 2024 | 12/07/2024 | 2024 | 0,5m x 0,5m x 0,5m | 60m x 50m x 32m | 120 x 100 x 64 = 192.000 | 60 | 23h 26min 17s | < 1 |
| Parametric detailed model (cement plaster) | Summer 2024 | 12/07/2024 | 2024 | 0,5m x 0,5m x 0,5m | 60m x 50m x 32m | 120 x 100 x 64 = 192.000 | 60 | 20h 39min 24s | < 1 |
| Parametric detailed model (lime plaster + reflective coating) | Summer 2024 | 12/07/2024 | 2024 | 0,5m x 0,5m x 0,5m | 60m x 50m x 32m | 120 x 100 x 64 = 192.000 | 60 | 23h 51min 23s | 1 |
| Parametric detailed model (cement plaster + reflective coating) | Summer 2024 | 12/07/2024 | 2024 | 0,5m x 0,5m x 0,5m | 60m x 50m x 32m | 120 x 100 x 64 = 192.000 | 60 | 20h 19min 24s | < 1 |
| Entire settlement with mitigative solutions (sun sails + pergolas with LAD = 0.15 m2/m3) | Summer 2024 | 12/07/2024 | 2024 | 1m x 1m x 1m | 515m x 196m x 91,5 m | 515 x 196 x 64 = 6.460.160 | 20 | 327h 53min 42s | 13,5 |
| Entire settlement with mitigative solutions (sun sails + pergolas LAD = 0.5 m2/m3) | Summer 2024 | 12/07/2024 | 2024 | 1m x 1m x 1m | 515m x 196m x 91,5 m | 515 x 196 x 64 = 6.460.160 | 14 | 247h 17min 47s | 10 |
| Entire settlement with mitigative solutions (sun sails + pergolas with LAD = 0.15 m2/m3 + water sprays) | Summer 2024 | 12/07/2024 | 2024 | 1m x 1m x 1m | 515m x 196m x 91,5 m | 515 x 196 x 64 = 6.460.160 | 60 | 314h 23min 3s | 13 |
| Entire settlement with mitigative solutions (sun sails + pergolas with LAD = 0.5 m2/m3 + water sprays) | Summer 2024 | 12/07/2024 | 2024 | 1m x 1m x 1m | 515m x 196m x 91,5 m | 515 x 196 x 64 = 6.460.160 | 14 | 314h 23min 3s | 13 |

# Thematic Bibliography

## *Historical centres: protection, conservation, planning, and landscape*

### Online resources

ANCSA n.d.: ANCSA – Associazione Nazionale Centri Storico Artistici, *Il dibattito*, n.d. https://www.ancsa.org/la-storia-e-larchivio/il-dibattito/ (last accessed: March 2024).

ANCSA 2024: ANCSA – Associazione Nazionale Centri Storico Artistici, *Chi siamo*, last updated 2024. https://www.ancsa.org/chi-siamo/ (last accessed: September 2025).

Region of Tuscany 2015: Region of Tuscany, *Piano di indirizzo territoriale con valenza di piano paesaggistico*, 2015. https://www.regione.toscana.it/-/piano-di-indirizzo-territoriale-con-valenza-di-piano-paesaggistico (last accessed: September 2025).

Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Milano 2021: Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Milano, *La tutela paesaggistica*, 2021. https://www.architettonicimilano.lombardia.beniculturali.it/compiti-istituzionali/tutela-paesaggistica-2/ (last accessed: September 2025).

### Bibliography

Angiuli 2015: A. Angiuli, *La genesi urbanistica del centro storico: dalla "Carta di Gubbio" alle nuove problematiche del risanamento*, in C. Lamberti, M.L. Campiani (eds.), *I centri storici tra norme e politiche*, Jovene Editore, Napoli 2015. https://aedon.mulino.it/atti/2015/centri_storici/angiuli.pdf (last accessed: September 2025)

Chiti 1998: M. P. Chiti, *La nuova nozione di "beni culturali" nel d.lg. 112/1998: prime note esegetiche*, in «Aedon», 1 (1998). https://aedon.mulino.it/archivio/1998/1/chiti.htm (last accessed: July 2025)

Clementi 2002: A. Clementi, *Dopo Urban. Verso una politica delle interdipendenze*, in P.C. Palermo (ed.), *Il programma urban e l'innovazione delle politiche urbane. Il senso dell'esperienza: interpretazioni e proposte*, Vol. 1, Franco Angeli, Milano 2002, pp. 19-29.

D'Alessio 1983: G. D'Alessio, *I centri storici. Aspetti giuridici*, Giuffrè editore, Milano 1983.

Fantini 2015: S. Fantini, *Il centro storico come bene paesaggistico a valenza culturale*, «Aedon», 2 (2015). https://aedon.mulino.it/atti/2015/centri_storici/fantini.pdf (last accessed: August 2025).

Ferro *et al.* 2024: L. Ferro, E. György, G. Oláh, J.T. Lopes, G. Sonkoly, S. Apolinário, N. Azevedo, J. Ricardo, *Gentrification and touristification in urban heritage preservation: threats and opportunities*, in «Cultural Trends», Taylor & Francis 2024, pp. 1–16. https://www.tandfonline.com/doi/full/10.1080/09548963.2024.2352407 (last accessed: August 2025).

Fiorani 2019: D. Fiorani, *Il futuro dei centri storici. Digitalizzazione e strategia conservativa*, Quasar, Rome 2019.

Giambruno 2007: M.C. Giambruno, *Per una storia del Restauro Urbano. Piani, strumenti e progetti per i centri storici*, Città Studi, Torino 2007.

Giovannoni 1928: G. Giovannoni, *Questioni urbanistiche*, in «L'ingegnere», 1928. https://www.cittaconquistatrice.it/gustavo-giovannoni-questioni-urbanistiche-1928/ (last accessed: September 2025).

Indovina, Savino 1997: F. Indovina, M. Savino, *I vantaggi dell'integrazione tra città storica e città moderna*, in B. Gabrielli (ed.), *La ciutat històrica dins la ciutat*, Ajuntament de Girona, Girona 1997.

Longhi, Ernesti 1995: G. Longhi, G. Ernesti, *1942-1992: fifty years from the general town planning act*, Istituto Universitario di Architettura di Venezia, Dipartimento di Urbanistica, Venezia 1995.

Lunardelli 2022: M. Lunardelli, *Le Soprintendenze Archeologia, Belle Arti e Paesaggio*, in «Rivista trimestrale di diritto pubblico, 4 (2022), pp. 1115–1148.

Marzocca 2007: R. Marzocca, *La nozione di bene culturale dalla Commissione Franceschini al nuovo Codice*, «Altalex», 2007. https://www.altalex.com/documents/news/2007/01/03/la-nozione-di-bene-culturale-dalla-commissione-franceschini-al-nuovo-codice (last accessed: August 2025).

Pane 1971: R. Pane, *Centro storico e centro antico*, in R. Pane, L. Cinalli, G. D'Angelo, R. di Stefano, C. Forte, S. Casiello, G. Fiengo, L. Santoro (eds.), *Il centro antico di Napoli. Restauro urbanistico e piano d'intervento*, vol. I, Edizioni Scientifiche Italiane, Napoli 1971, pp. 13-15.

Roccella 2005: A. Roccella, *Governo del territorio: rapporti con la tutela dei beni culturali e l'ordinamento civile*, in «Le Regioni», 6 (2005), pp. 1255-1265.

Scattoni, Falco 2011: P. Scattoni, E. Falco, *Why Italian planning is worth studying*, in «IJPP - Italian Journal of Planning Practice», I, 1 (2011), pp. 4–32.

Videtta 2012: C. Videtta, *I centri storici al crocevia tra disciplina dei beni culturali, disciplina del paesaggio e urbanistica: profili critici,* in «Aedon», 3 (2012). https://aedon.mulino.it/archivio/2012/3/videtta.htm (last accessed: September 2025).

Vitruvius 1914: Vitruvius, *The Ten Books on Architecture*, Harvard University Press, Cambridge (USA) 1914.

### Laws, Regulations, Reports and Guidelines

ANCSA – Associazione Nazionale Centri Storico Artistici 1960: ANCSA – Associazione Nazionale Centri Storico Artistici, *The First Gubbio Charter 1960* [*La prima Carta di Gubbio 1960*], Gubbio 1960. https://www.ancsa.org/la-storia-e-larchivio/la-prima-carta-di-gubbio-1960/ (last accessed: July 2025).

ANCSA 1990: ANCSA – Associazione Nazionale Centri Storico Artistici, *The Second Gubbio Charter 1990* [La seconda Carta di Gubbio 1990], Gubbio 1990. https://www.ancsa.org/la-storia-e-larchivio/la-seconda-carta-di-gubbio-1990/ (last accessed: August 2025).

ANCSA 2021: ANCSA – Associazione Nazionale Centri Storico Artistici, *Statute* [*Statuto*], Rome 2021. https://www.ancsa.org/wp-content/uploads/2021/04/Nuovo-Statuto-ANCSA.pdf (last accessed: July 2025).

Ceccarelli *et al.* 1992: P. Ceccarelli, F. Choay, W. Desimpelaere, A. Filali Baba, B. Gabrielli, P. Malone, C. Storelli, J. Tanghe, M.L.Valente Pereira, *Charter of City Rights* or *Declaration of Genoa* [*Carta dei Diritti delle Città* o *Dichiarazione di Genova*], Genoa 1992.

https://www.itc.cnr.it/ba/re/Documenti/dichiarazione%20di%20Genova%201992.htm (last accessed: August 2025).

Commissione Franceschini 1967: Commissione Franceschini, *For the Safeguarding of Cultural Heritage in Italy. Proceedings and Documents of the Commission of Inquiry for the Protection and Enhancement of the Historical, Archaeological, Artistic, and Landscape Heritage* [*Per la Salvezza dei Beni Culturali in Italia. Atti e documenti della Commissione d'indagine per la tutela e la valorizzazione del patrimonio storico, archeologico, artistico e del paesaggio*], 3 vols., Casa editrice Colombo, Roma 1967. https://icar.cultura.gov.it/wayback/ICARWEB/20161214095930mp_/http:/www.icar.beniculturali.it/biblio/pdf/Studi/franceschini.pdf (last accessed: August 2025).

Ministry of Education 1972: Ministry of Education, *Carta del Restauro 1972,* in «Bollettino d'Arte», V serie, 2 (1972), Istituto Poligrafico dello Stato, Libreria dello Stato, pp. 122–129.

CLRAE 1992: CLRAE – Council of Europe's Standing Conference of Local and Regional Authorities of Europe, *European Urban Charter*, Strasbourg 1992. https://rm.coe.int/168071923d#P12_318 (last accessed: August 2025).

Council of Europe 2000: Council of Europe, *Landscape Convention*, Florence 2000. https://rm.coe.int/16807b6bc7 (last accessed: August 2025).

Gazzola *et al.* 1964: P. Gazzola, R. Lemaire, J. Bassegoda Nonell, L. Benavente, D. Boskovic, H. Daifuku, P. L. de Vrieze, H. Langberg, M. Matteucci, J. Merlet, C. Flores Marini, R. Pane *et al.*, *International Charter for the Conservation and Restoration of Monuments and Sites* (*Venice Charter*), 2nd International Congress of Architects and Technicians of Historic Monuments (Venice, May 1964), ratified by ICOMOS – International Council on Monuments and Sites in 1965.

ICOMOS 1987: ICOMOS, *Charter for the Conservation of Historic Towns and Urban Areas [Washington Charter],* Paris 1987. https://civvih.icomos.org/wp-content/uploads/2022/03/Charter-of-Washington_10_1987.pdf (last accessed: October 2025).

Italian Government 1939a: Italian Government, Law 1 June 1939, No. 1089 *Protection of Items of Artistic or Historical Interest* [*Tutela delle cose d'interesse Artistico o Storico*], in «Gazzetta Ufficiale del Regno d'Italia», No. 184, 8 August 1939.

Italian Government 1939b: Italian Government, Law 29 June 1939, No. 1497, *Protection of Natural Beauties* [*Protezione delle bellezze naturali*], in «Gazzetta Ufficiale del Regno d'Italia», No. 241, 14 October 1939.

Italian Government 1942: Italian Government, Law 17 August 1942, No. 1150, *Planning Law* [*Legge Urbanistica*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 244, 16 October 1942. https://www.bosettiegatti.eu/info/norme/statali/1942_1150.htm (last accessed: August 2025).

Italian Government 1964: Italian Government, Law 26 April 1964, No. 310, *Establishment of a Commission of Inquiry for the Protection and Enhancement of the Historical, Archaeological, and Artistic Heritage and the Landscape* [*Costituzione di una Commissione d'indagine per la tutela e la valorizzazione del patrimonio storico, archeologico, artistico e del paesaggio*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 119, 15 May 1964.

Italian Government 1967: Italian Government, Law 6 August 1967, No. 765, *Amendments and additions to the urban planning law of 17 August 1942, n. 1150* [*Modifiche ed integrazioni alla legge urbanistica 17 agosto 1942, n. 1150*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 218, 31 August 1967. https://www.gazzettaufficiale.it/eli/id/1967/08/31/067U0765/sg (last accessed: August 2025).

Italian Government 1968: Italian Government, Ministerial Decree of 2 April 1968, No., 1444, *Mandatory limits of building density, height, distance between manufacturers and maximum ratios between spaces intended for residential and production settlements and public spaces or spaces reserved for collective activities, public greenery or parking spaces to be observed for the purposes of the formation of new urban planning instruments or the revision of existing ones, pursuant to art. 17 of law 6 August 1967, no. 765* [*Limiti inderogabili di densita' edilizia, di altezza, di distanza fra i fabbricanti e rapporti massimi tra spazi destinati agli insediamenti residenziali e produttivi e spazi pubblici o riservati alle attivita' collettive, al verde pubblico o a parcheggi da osservare ai fini della formazione dei nuovi strumenti urbanistici o della revisione di quelli esistenti, ai sensi dell'art. 17 della legge 6 agosto 1967, n. 765*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 97, 16 April 1968. https://www.gazzettaufficiale.it/eli/id/1968/04/16/1288Q004/sg (last accessed: August 2025).

Italian Government 1975: Italian Government, Law 22 July 1975, No. 382, *Provisions on regional governance and the organisation of public administration* [*Norme sull'ordinamento regionale e sulla organizzazione della pubblica amministrazione*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 220, 20 August 1975. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1975-07-22;382!vig= (last accessed: September 2025).

Italian Government 1977: Italian Government, Presidential Decree 24 July 1977, No. 616, *Implementation of the delegation provided for in Article 1 of Law No. 382 of 22 July 1975* [*Attuazione della delega di cui all'art. 1 della legge 22 luglio 1975, n. 382*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 234, 29 August 1977. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.del.presidente.della.repubblica:1977-07-24;616!vig= (last accessed: September 2025).

Italian Government 1978: Italian Government, Law 5 August 1978, No. 457, *Rules for residential construction* [*Norme per l'edilizia residenziale*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 231, 19 August 1978. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1978-08-05;457~com1-num6 (last accessed: August 2025).

Italian Government 1985a: Italian Government, Law 28 February 1985, No. 47, *Provisions concerning the control of urban planning and building activities. Administrative and criminal sanctions* [*Norme in materia di controllo dell'attività urbanistico-edilizia. Sanzioni amministrative e penali*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 53, 2 March 1985. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1985-02-28;47~art35-com3-letd (last accessed: September 2025).

Italian Government 1985b: Italian Government, Law 8 August 1985, No. 431, *Conversion into law, with amendments, of the legislative decree of 27 June 1985, n. 312, containing urgent provisions for the protection of areas of particular environmental interest. Additions to article 82 of Presidential Decree No. 616 of 24 July 1977* [*Conversione in legge, con modificazioni, del decreto-legge 27 giugno 1985, n. 312, recante disposizioni urgenti per la tutela delle zone di particolare interesse ambientale. Integrazioni dell'articolo 82 del decreto del Presidente della Repubblica 24 luglio 1977, n. 616*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 197, 22 August 1985. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1985-08-8;431!vig= (last accessed: September 2025).

Italian Government 1992: Italian Government, Law 17 February 1992, No. 179, *Regulations*

*for public housing* [*Norme per l'edilizia residenziale pubblica*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 50, 29 February 1992. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1992;179 (last accessed: August 2025).

Italian Government 1993a: Italian Government, Law 4 December 1993, No. 493, *Conversion into law, with amendments, of the legislative decree of 5 October 1993, n. 398, containing provisions for the acceleration of investments to support employment and for the simplification of construction procedures* [*Conversione in legge, con modificazioni, del decreto-legge 5 ottobre 1993, n. 398, recante disposizioni per l'accelerazione degli investimenti a sostegno dell'occupazione e per la semplificazione dei procedimenti in materia edilizia*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 285, 4 December 1993. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1993-12-04;493!vig= (last accessed: August 2025).

Italian Government 1997a: Italian Government, Law 15 March 1997, No. 59, *Delegation to the Government for the transfer of functions and responsibilities to Regions and local authorities, for the reform of public administration and for administrative simplification* [*Delega al Governo per il conferimento di funzioni e compiti alle regioni ed enti locali, per la riforma della pubblica amministrazione e per la semplificazione amministrativa*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 63, 17 March 1997. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1997-03-15;59!vig= (last accessed: September 2025).

Italian Government 1997b: Italian Government, Ministerial Decree 22 October 1997, *Approval of the call for proposals concerning the financing of experimental interventions in the field of subsidized residential housing to be implemented within the framework of urban regeneration programs known as "Neighborhood Contracts"* [*Approvazione del bando di gara relativo al finanziamento di interventi sperimentali nel settore dell'edilizia residenziale sovvenzionata da realizzare nell'ambito di programmi di recupero urbano denominati "Contratti di quartiere"*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 24, 30 January 1998. https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=1998-01-30&atto.codiceRedazionale=098A0470 (last accessed: August 2025).

Italian Government 1998a: Italian Government, Ministerial Decree 20 May 1998, *Amendments to the Decree of 22 October 1997 approving the call for proposals concerning the financing of experimental interventions in the field of subsidized residential housing to be implemented within the framework of urban regeneration programs known as "Neighborhood Contracts"* [*Modificazioni al decreto 22 ottobre 1997 recante approvazione del bando di gara relativo al finanziamento di interventi sperimentali nel settore dell'edilizia residenziale sovvenzionata da realizzare nell'ambito di programmi di recupero urbano denominati "Contratti di quartiere"*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 119, 25 May 1998. https://www.gazzettaufficiale.it/eli/id/1998/05/25/098A4365/sg (last accessed: August 2025).

Italian Government 1998b: Italian Government, Ministerial Decree 8 October 1998b, *Promotion of innovative programs in the urban context called "Urban Regeneration and Sustainable Territorial Development Programs"* [*Promozione di programmi innovativi in ambito urbano denominati "Programmi di riqualificazione urbana e di sviluppo sostenibile del territorio"*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 278, 27 November 1998, No. 195. https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=1998-11-27&atto.codiceRedazionale=98A10237&elenco30giorni=false (last accessed: August 2025).

Italian Government 2001a: Italian Government, Presidential Decree 6 June 2001, No. 380, *Consolidated Act on Legislative and Regulatory Provisions in the Field of Building Activities* [*Testo unico delle disposizioni legislative e regolamentari in materia edilizia*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 245, 20 October 2001. https://www.bosettiegatti.eu/info/norme/statali/2001_0380.htm (last accessed: September 2025).

Italian Government 2001b: Italian Government, Ministerial Decree 27 December 2001b, *Innovative Programs in the Urban Context* [*Programmi innovativi in ambito urbano*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 162, 12 July 2002, Ordinary Supplement No. 142. https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=2002-07-12&atto.codiceRedazionale=02A08171&elenco30giorni=false (last accessed: August 2025).

Italian Government 2004: Italian Government, Legislative Decree 22 January 2004, No. 42, *Code of Cultural Heritage and Landscape* [*Codice dei beni culturali e del paesaggio*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 45, 24 February 2004, Ordinary Supplement No. 28. https://www.bosettiegatti.eu/info/norme/statali/2004_0042.htm (last accessed: August 2025).

Italian Government 2008a: Italian Government, Legislative Decree 26 March 2008, No. 62, *Further supplementary and corrective provisions of Legislative Decree No. 42 of 22 January 2004, concerning cultural heritage* [*Ulteriori disposizioni integrative e correttive del decreto legislativo 22 gennaio 2004, n. 42, in relazione ai beni culturali*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 84, 09 April 2008. https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=2008-04-09&atto.codiceRedazionale=008g0092Elenco 30giorni=false (last accessed: August 2025).

Italian Government 2008b: Italian Government, Decree-Law 25 June 2008, No. 112, *Urgent provisions for economic development, simplification, competitiveness, stabilization of public finances, and tax equalization* [*Disposizioni urgenti per lo sviluppo economico, la semplificazione, la competitività, la stabilizzazione della finanza pubblica e la perequazione Tributaria*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 147, 25 June 2008. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legge:2008-06-25;112 (last accessed: September 2025).

Italian Government 2017a: Italian Government, Presidential Decree 31 February 2017, No. 31, *Regulation identifying interventions exempt from landscape authorization or subject to simplified authorization procedures* [*Regolamento recante individuazione degli interventi esclusi dall'autorizzazione paesaggistica o sottoposti a procedura autorizzatoria semplificata*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 68, 22 March 2017. https://www.bosettiegatti.eu/info/norme/statali/2017_0031.htm (last accessed: September 2025).

Italian Government 2019: Italian Government, Law 27 December 2019, No. 160, *State Budget for the Financial Year 2020 and Multi-Year Budget for the Three-Year Period 2020–2022* [*Bilancio di previsione dello Stato per l'anno finanziario 2020 e bilancio pluriennale per il triennio 2020–2022*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 304, 30 December 2019.https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:2019-12-27;160 (last accessed: September 2025).

Italian Government 2020a: Italian Government, Decree-Law 19 May 2020, No. 34, *Urgent Measures in the Field of Health, Support for Work and the Economy, and Social Policies Related to*

*the Epidemiological Emergency by COVID-19* [*Misure urgenti in materia di salute, sostegno al lavoro e all'economia, nonché di politiche sociali connesse all'emergenza epidemiologica da COVID-19*], converted into Law No. 77 of 17 July 2020, in «Gazzetta Ufficiale della Repubblica Italiana», No. 128, 19 May 2020. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legge:2020;34 (last accessed: September 2025).

MiBACT 2018a: MiBACT – Ministry of Cultural Heritage and Tourism, *Stati Generali del Paesaggio*, 2018. https://aedon.mulino.it/archivio/2018/1/StatiGeneraliPaesaggio.pdf (last accessed: September 2025).

MiBACT 2018b: MiBACT, *Carta nazionale del paesaggio. Elementi per una Strategia per il paesaggio italiano*, 2018. https://www.soprintendenzapdve.beniculturali.it/wp-content/uploads/2021/04/Carta-Nazionale-del-Paesaggio.pdf (last accessed: September 2025).

UNESCO - United Nations Educational, Scientific and Cultural Organization 1992: UNESCO, *Convention Concerning the Protection of the World Cultural and Natural Heritage*, Santa Fe 1992. https://whc.unesco.org/archive/1992/whc-92-conf002-12e.pdf (last accessed: August 2025).

UNESCO 2011: UNESCO – United Nations Educational, Scientific and Cultural Organization, *Recommendation on Historic Urban Landscape*, Paris 2011. http://whc.unesco.org/en/hul/ (last accessed: September 2025).

***Small villages, depopulation, and inner areas issues***

*Italian and European context*

**Online resources**

ANCI 2019: ANCI – Associazione Nazionale Comuni Italiani, *Atlante dei Piccoli Comuni*, 2019. https://www.anci.it/atlante-dei-piccoli-comuni/ (last accessed: March 2024).

Borghi Autentici d'Italia n.d.: Borghi Autentici d'Italia, *L'associazione*, n.d. https://www.borghiautenticiditalia.it/lassociazione (last accessed: September 2025).

ANCI - Associazione Nazionale Comuni Italiani *et al.* 2018: ANCI, Borghi Autentici d'Italia, Legambiente, *et al.*, *Plea for the Save the Villages Law* [*Appello per la Legge Salva Borghi*], 2018. https://www.legambiente.it/wp-content/uploads/appello_legge_salvaborghi.pdf (last accessed: September 2025).

CSO 2019: CSO – Central Statistics Office of Ireland, *Urban and Rural Life in Ireland*, 2019. https://ie-cso.maps.arcgis.com/apps/webappviewer/index.html?id=359df7944d554cdeb14d220b36224d4c (last accessed: September 2025).

CSO - Central Statistics Office of Ireland 2022: CSO – Central Statistics Office of Ireland, *Census of Population 2022 Profile 1 - Population Distribution and Movements*, 2022. https://www.cso.ie/en/releasesandpublications/ep/p-cpp1/censusofpopulation2022profile1-populationdistributionandmovements/populationdistribution/ (last accessed: September 2025).

Dipartimento per le politiche di coesione e per il sud 2022: Dipartimento per le politiche di coesione e per il sud, *Aggiornamento 2020 della mappa delle Aree Interne. Nota tecnica NUVAP*, 2022. https://politichecoesione.governo.it/media/2831/20220214-mappa-ai-2020-nota-tecnica-nuvap_rev.pdf (last accessed: August 2025).

Europa Nostra 2025: Europa Nostra, *European Heritage Alliance*, last update 2025. https://www.europanostra.org/our-work/policy/european-heritage-alliance/ (last accessed: August 2025).

European Commission 2021a: European Commission, *Cohesion Policy*, 2021. https://ec.europa.eu/regional_policy/policy/what/investment-policy_en (last accessed: August 2025).

European Commission n.d.a: European Commission, *European Agricultural Fund for Rural Development (EAFRD)*, n.d. https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/european-agricultural-fund-rural-development-eafrd_en (last accessed: September 2025).

European Commission n.d.b: European Commission, *European Social Fund Plus,* n.d. https://european-social-fund-plus.ec.europa.eu/en (last accessed: September 2025).

ENRD - European Network for Rural Development 2021: European Network for Rural Development, *LEADER/CLLD*, last update 2021. https://ec.europa.eu/enrd/leader-clld_en.html (last accessed: September 2025).

European Union 2017: European Union, *Europe 2020: the European Union strategy for growth and employment*, 2017. https://eur-lex.europa.eu/IT/legal-content/summary/europe-2020-the-european-union-strategy-for-growth-and-employment.html (last accessed: September 2025).

European Union 2025: European Union, *Next Generation EU*, last update 2025. https://next-generation-eu.europa.eu/index_en (last accessed: September 2025)

European Union n.d.a: European Union, *Rural Pact Community Platform. Learn more about the Pact*, n.d. https://ruralpact.rural-vision.europa.eu/rural-pact_en (last accessed: September 2025)

European Union n.d.b: European Union, *Rural toolkit*, n.d. https://funding.rural-vision.europa.eu/?lng=en (last accessed: September 2025)

FAI - Fondo Ambiente Italiano 2022: FAI – Fondo Ambiente Italiano, *Servono subito i Piani paesaggistici regionali*, 2022. https://fondoambiente.it/news/servono-subito-i-piani-paesaggistici-regionali/ (last accessed: September 2025).

I Borghi più belli d'Italia 2025: I Borghi più belli d'Italia, *L' Associazione "I Borghi più belli d'Italia"*, last updated 2025. https://borghipiubelliditalia.it/ (last accessed: September 2025).

ISTAT - Istituto Nazionale di Statistica 2025: ISTAT – Istituto Nazionale di Statistica, *Popolazione residente per sesso, età e stato civile al 1° gennaio 2025*, 2025 https://demo.istat.it/app/?i=POS (last accessed: August 2025).

Office for National Statistics 2025: Office for National Statistics, *2021 Rural Urban Classification*, last updated 2025. https://www.ons.gov.uk/methodology/geography/geographicalproducts/ruralurbanclassifications/2021ruralurbanclassification (last accessed: September 2025).

Pianigiani 1907: O. Pianigiani, *Borgo*, in «Vocabolario etimologico della lingua italiana», Società editrice Dante Alighieri, Rome 1907 https://www.etimo.it/?term=borgo&find=Cerca (last accessed: September 2025).

Palazzo Chigi 2023: Palazzo Chigi, *Piano nazionale per la riqualificazione dei piccoli comuni, conferenza stampa del Ministro Musumeci*, 14 luglio 2023. https://www.youtube.com/watch?v=1fxgm-0mqqc&t=718s (last accessed: August 2025).

Touring Club Italiano n.d: Touring Club Italiano, *Bandiere Arancioni*, n.d. https://www.touringclub.it/cosa-facciamo/bandiere-arancioni (last accessed: September 2025).

Treccani 1930: Treccani, *Borgo*, in «Enciclopedia Italiana», Istituto della Enciclopedia Italiana, Rome 1930, https://www.treccani.it/enciclopedia/borgo_(Enciclopedia-Italiana)/ (last accessed: September 2025).

UNCEM - Unione Nazionale Comuni Comunità Enti Montani 2022: UNCEM – Unione Nazionale Comuni Comunità Enti Montani, *Bando Borghi del PNRR. Lettera aperta del Presidente UNCEM*, 2022. https://uncem.it/bando-borghi-del-pnrr-lettera-aperta-del-presidente-uncem/ (last accessed: September 2025).

Union des Villes et Communes de Wallonie 2011: Union des Villes et Communes de Wallonie, *Le développement territorial durable: les défis des communes rurales*, 2011. https://www.uvcw.be/ruralite/focus/art-2311#_ftn1%C3%A0 (last accessed: August 2025).

World Bank Group 2024: World Bank Group, *Rural population (% of total population) - Ireland*, 2024. https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=IE (last accessed: August 2025).

**Bibliography**

Amendola 2019: G. Amendola, *Centri storici e tessuti sociali*. In S. Storchi (ed.), *Centri storici e città*, Monte Università Parma, Parma 2019, pp. 9–14.

Amodio 2021: T. Amodio, *A reading of marginality through depopulation and abandonment in small municipalities*, in «Bollettino della Associazione Italiana di Cartografia», 172 (2021), pp. 50–65.

Barca *et al.* 2014: F. Barca, P. Casavola, S. Lucatelli (eds.), *A Strategy for Inner Areas in Italy: Definition, Objectives, Instruments and Governance*, Ministry of Economy and Finance, Rome 2014.

Barbera *et al.* 2022: F. Barbera, D. Cersosimo, A. De Rossi, *Il paese dei borghi. Introduzione*, in F. Barbera, D. Cersosimo, A. De Rossi (eds.), *Contro i borghi. Il belpaese che dimentica i paesi*, Donzelli Editore, Rome 2022.

Battisti 2020: A. Battisti, *Abitare le aree interne per vivere insieme passato e futuro*, in S. Damiano (ed.), *Il recupero dei centri storici minori*, Proceedings of the VII International Widespread Conference (San Venanzo - Terni, September 2019), Palombi Editori, Modena 2020, pp. 81–86.

Canevari 2007: A. Canevari, *Piccoli centri storici in movimento. Piani e progetti per la valorizzazione dei centri storici minori*, in M. Giambruno (ed.), *Per una storia del Restauro Urbano*, CittàStudi Edizioni, Torino 2007, pp. 287–296.

Carozzi, Mioni 1970: C. Carozzi, A. Mioni (eds.), *L'Italia in formazione. Ricerche e saggi sullo sviluppo urbanistico del territorio nazionale*, De Donato, Bari 1970.

Cersosimo 2022: D. Cersosimo, *PNRR e Mezzogiorno*, in «Rivista di cultura e di politica», Special *Un Piano per il Paese*, Il Mulino, Bologna 2022. https://www.rivistailmulino.it/a/pnrr-e-mezzogiorno (last accessed: September 2025).

Cersosimo, Donzelli 2020: D. Cersosimo, C. Donzelli (eds.), *Manifesto per riabitare l'Italia*, Donzelli Editore, Rome 2020.

Cervellati 1991: P.L. Cervellati, *La città bella. Il recupero dell'ambiente urbano*, Società editrice Il Mulino, Bologna, 1991.

Charmes 2019: E. Charmes, *La Revanche des villages. Essai sur la France périurbaine*, Seuil, Paris 2019.

Cinieri, Garzulino 2021: V. Cinieri, A. Garzulino, *Emergenza sanitaria ed edilizia: una possibile opportunità per riabitare i piccoli centri*, in «Territorio», 97-supplement (2021), pp. 119–124.

Clemente 2022: P. Clemente, *Chiamiamoli paesi, non borghi*, in F. Barbera, D. Cersosimo, A. De Rossi (eds.), *Contro i borghi. Il belpaese che dimentica i paesi*, Donzelli Editore, Rome 2022.

Comitato di Coordinamento per i Borghi turistici italiani 2022: Comitato di Coordinamento per i Borghi turistici italiani, *La Carta Nazionale dei Borghi*, in «Economia della Cultura», 1, Società editrice il Mulino, Bologna 2022, pp. 129–137.

Corazza 2022: L. Corazza, *Potrà il PNRR rilanciare le aree interne?*, in «Rivista di cultura e di politica», Special *Un Piano per il Paese*, Il Mulino, Bologna 2022. https://www.rivistailmulino.it/a/potr-il-pnrr-rilanciare-le-aree-interne (last accessed: September 2025).

De Rossi 2018: A. De Rossi (ed.), *Riabitare l'Italia. Le aree interne tra abbandoni e riconquiste*, Donzelli editore, Roma 2018.

Farinelli 2006: F. Farinelli, *Prima della città, dopo la metropoli*, in M. Romano (ed.), *Piccole città, borghi e villaggi*, Vol. 1, Touring Club Italiano, Milan 2006, pp. 13–15.

Ferlenga 2017: A. Ferlenga, *Ritorno al futuro. Borghi e centri storici come materiale per le città di domani*, in B. Albrecht, A. Magrin (a cura di), *Il bel Paese. 1 progetto per 22.621 centri storici*, Rubbettino, Soveria Mannelli 2017, pp. 14–19.

Güler, Kâhya 2019: K. Güler, Y. Kâhya, *Developing an approach for conservation of abandoned rural settlements in Turkey*, in «A/Z ITU journal of Faculty of Architecture», Vol. 16, 1 (2019), pp. 97–115.

Hospers, Reverda 2015: G.J. Hospers, N. Reverda, *Managing Population Decline in Europe's Urban and Rural Areas*, Springer, New York, London 2015.

Ietri, Pagetti 2019: D. Ietri, F. Pagetti, *The definition of 'inner peripheries': indicators and territorial units*, in «Bollettino della ASSOCIAZIONE ITALIANA di CARTOGRAFIA», 165 (2019), pp. 89-97.

Jordan, Wright 2023: D. Jordan, A. Wright, *Starting the conversation for a town centre management framework for small towns in rural places: An Irish context*, in «Journal of Rural Studies», 97 (2023), pp. 395-404.

Kealy 2020: L. Kealy, *Their history is a grain of wheat*, in A.M. Oteri, G. Scamardì (eds.), *One needs a town. Studies and perspectives for abandoned or depopulated small towns*, ArcHistoR EXTRA 7 (2020), Supplement to «ArcHistoR», 13, pp. 96–113.

Landi 2023: A. Landi, *Italia Minore si Svela: conservazione e innovazione per rivitalizzare i borghi*, in «Authorea», 2023, pp. 1–10.

Menegus 2022: G. Menegus, *Bando Borghi e autonomie territoriali*, in «LE REGIONI», 5 (2022),

pp. 931–961.

Monardo 2023: B. Monardo, *Rigenerare i centri storici minori. L'Urbanistica delle reti per nuovi progetti di territorio*, in P. Casacchia (ed.), *Accessibilità e inclusività nei centri storici minori*, Edizioni RomaTre Press, Rome 2023, pp. 55–66.

Morgan 2017: K. Morgan, *Nurturing novelty: Regional innovation policy in the age of smart specialisation*, in «Environment and Planning C: Politics and Space», 35, 4 (2017), pp. 569–583.

Mortara 1970: G. Mortara, *Cause di sviluppo delle grandi città*, in C. Carozzi, A. Mioni (eds.), *L'Italia in formazione. Ricerche e saggi sullo sviluppo urbanistico del territorio nazionale*, De Donato, Bari 1970, pp. 78–96.

Oswalt 2006: P. Oswalt (ed.), *Shrinking Cities, Volume 1: International Research*, Hatje Cantz Verlag, Ostfildern-Ruit 2006.

Oteri 2020: A.M. Oteri, *Strategies and policies for relaunching depopulated small towns in inner areas: a human scale perspective*, in A.M. Oteri, G. Scamardì (eds.), *One needs a town. Studies and perspectives for abandoned or depopulated small towns*, ArcHistoR EXTRA 7 (2020), Supplement to «ArcHistoR», 13, pp. 40–59.

Pracchi, Oteri 2023: V. N. Pracchi, A. M. Oteri, *The "Unsustainable" Fascination of the Hamlets. Firsts Data and a Reflection on the Competition Announcement "Attrattività dei borghi storici"*, in «ArcHistoR», 19 (2023), pp. 163–201.

Pultrone 2020: G. Pultrone, *The Challenge of Inner Areas: form Problematic Areas to Places of Opportunities for a Better Future of Marginal Territories*, in A.M. Oteri, G. Scamardì (eds.), *One needs a town. Studies and perspectives for abandoned or depopulated small towns*, ArcHistoR EXTRA 7 (2020), Supplement to «ArcHistoR», 13, pp. 982-1001.

Romano 2006: M. Romano, *La città come opera d'arte*, in M. Romano (ed.), *Dentro l'Italia. Piccole città, borghi e villaggi*, vol. 1, Touring club italiano, Milan 2006, pp. 11-12.

Sanzaro 2022: D. Sanzaro, *Prospettive per la conservazione dei centri storici in via di abbandono. Strumenti, metodi e buone pratiche per il patrimonio costruito delle aree interne*, PhD dissertation, University of Catania – Department of Civil Engineering and Architecture, PhD Program in Assessment and Mitigation of Urban and Territorial Risks, XXXV ciclo, AY 2019/2022, supervisor: A. Cancelliere.

Sau 2018: A. Sau, *La rivitalizzazione dei borghi e dei centri storici minori come strumento per il rilancio delle aree interne*, in «federalismi.it», 3/201 (2018).

Scamardì 2020: G. Scamardì, *History of Abandonment. Reasons, Consequences, Transformations*, in A.M. Oteri, G. Scamardì (eds.), *One needs a town. Studies and perspectives for abandoned or depopulated small towns*, «ArcHistoR EXTRA», 7, 13 (2020), pp. 18–39.

Servillo *et al.* 2016: L. Servillo, A.P. Russo, F. Barbera, G. Carrosio, *Inner Peripheries: towards an EU placebased agenda on territorial peripherality,* in «IJPP – Italian Journal of Planning Practice», VI, 1 (2016), pp. 42–75.

Severgnini 2022: F. Severgnini, *L'Intervento "Attrattività dei borghi" tra PNRR e bandi per i borghi storici*, in S. Martino, N. Gussoni, M. Cabras (eds.), *L'esperienza lombarda dei Bandi "Attrattività dei borghi". Un percorso di partecipazione condivisa*, Regione Lombardia, ANCI, Fondazione Cariplo, 2022, pp. 15–20.



Zetter 1982: J. Zetter, *European campaign for urban renaissance*, in «Landscape Research», 7, 2 (1982), pp. 28–29.

**Laws, Regulations, Reports and Guidelines**

ANPP - Association Nationale des Pôles territoriaux et des Pays 2022: ANPP – Association Nationale des Pôles territoriaux et des Pays, *Note de synthèse. Contrats de réciprocité*, 2022. https://www.anpp.fr/wp-content/uploads/2022/08/Contrats-de-reciprocite.pdf (last accessed: August 2025).

ESPON - European Spatial Planning Observation Network 2017: ESPON – European Spatial Planning Observation Network, *PROFECY – Processes, Features and Cycles of Inner Peripheries in Europe (Inner Peripheries: National territories facing challenges of access to basic services of general interest). Final Report. Executive Summary*, ESPON EGTC, Luxembourg 2017. https://archive.espon.eu/sites/default/files/attachments/D5%20Executive%20Summary%20PROFECY.pdf (last accessed: August 2025).

ESPON 2018: ESPON, *Inner peripheries in Europe. Possible development strategies to overcome their marginalising effects*, ESPON EGTC, Luxembourg 2018. https://archive.espon.eu/sites/default/files/attachments/ESPON-Policy-Brief-Inner-Peripheries.pdf (last accessed: August 2025).

European Commission 2010: European Commission, *Europe 2020. A European strategy for smart, sustainable and inclusive growth*, 2010. https://www.eesc.europa.eu/en/our-work/opinions-information-reports/opinions/role-and-priorities-cohesion-policyeu-2020 (last accessed: August 2025).

European Commission 2019a: European Commission, *Urban agenda for the EU Multi-level governance in action*, Brussels 2019. https://ec.europa.eu/regional_policy/sources/brochure/urban_agenda_eu_en.pdf (last accessed: August 2025).

Government of Ireland 2018: Government of Ireland, *National Vacant Housing Reuse Strategy 2018-2021*, 2018. https://assets.gov.ie/static/documents/national-vacant-housing-reuse-strategy-2018-2021-progress-report-may-2020.pdf (last accessed: August 2025).

Government of Ireland 2021: Government of Ireland, *Our Rural Future. Rural Development Policy 2021-2025*, 2021. https://assets.gov.ie/static/documents/our-rural-future.pdf (last accessed: August 2025).

Government of Ireland 2023a: Government of Ireland, *Town Centre First. A Policy Approach for Irish Towns*, 2023. https://towncentrefirst.ie/wp-content/uploads/2023/11/Town-Centre-First-Policy.pdf (last accessed: August 2025).

Italian Government 1994: Italian Government, Law 31 January 1994, No. 97, *New provisions for mountain areas* [*Nuove disposizioni per le zone montane*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 32, 9 February 1994. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1994-01-31;97 (last accessed: September 2025).

Italian Government 2000: Italian Government, Legislative Decree 18 August 2000, *Consolidated Act on the Laws Governing Local Authorities* [*Testo unico delle leggi sull'ordinamento degli enti locali*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 227, 28 September 2000. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2000-08-18;267

(last accessed: September 2025).

Italian Government 2017b: Italian Government, Law 6 October 2017, No. 158, *Measures for the Support and Enhancement of Small Municipalities, as well as Provisions for the Redevelopment and Recovery of their Historic Centres* [*Misure per il sostegno e la valorizzazione dei piccoli comuni, nonché disposizioni per la riqualificazione e il recupero dei centri storici dei medesimi comuni*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 256, 2 November 2017. https://www.gazzettaufficiale.it/eli/id/2017/11/02/17G00171/sg (last accessed: August 2025).

Italian Government 2020b: Italian Government, Law 11 September 2020, No. 120, *Conversion into law, with amendments, of Decree-Law No. 76 of July 16, 2020, containing urgent measures for simplification and digital innovation* [*Conversione in legge, con modificazioni, del decreto-legge 16 luglio 2020, n. 76, recante misure urgenti per la semplificazione e l'innovazione digitale*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 228, 14 September 2020. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:2020-09-11;120 (last accessed: September 2025).

Italian Government 2021a: Italian Government, *Piano Nazionale di Ripresa e Resilienza (PNRR)*, Government of Italy, Rome 2021. https://www.governo.it/sites/governo.it/files/PNRR.pdf (last accessed: September 2025)

Italian Government 2021b: Italian Government, Decree-Law 31 May 2021, No. 77, *Governance of the National Recovery and Resilience Plan and Initial Measures to Strengthen Administrative Structures and to Accelerate and Streamline Procedures* [*Governance del Piano nazionale di ripresa e resilienza e prime misure di rafforzamento delle strutture amministrative e di accelerazione e snellimento delle procedure*], converted into Law No. 108 of 29 July 2021, in «Gazzetta Ufficiale della Repubblica Italiana», No. 181, 30 July 2021. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legge:2021;77~art8 (last accessed: September 2025).

Italian Government 2021c: Italian Government, Ministerial Decree 23 July 2021, *Definition of the list of small municipalities falling within the categories referred to in Article 1, paragraph 2, of Law No. 158 of 6 October 2017* [*Definizione dell'elenco dei piccoli comuni che rientrano nelle tipologie di cui all'articolo 1, comma 2, della legge 6 ottobre 2017, n. 158*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 220, 14 September 2021. https://www.gazzettaufficiale.it/eli/id/2021/09/14/21A05365/sg (last accessed: August 2025).

Italian Government 2021d: Italian Government, Decree of the President of the Council of Ministers 30 September 2021, No. 296, *Procedures for the allocation, deadlines, access modalities and reporting of contributions under the Fund for Marginal Municipalities, aimed at supporting residents in disadvantaged municipalities, for each of the years 2021 to 2023* [*Modalità di ripartizione, termini, modalità di accesso e rendicontazione dei contributi a valere sul Fondo comuni marginali, al fine di realizzare interventi di sostegno alle popolazioni residenti nei comuni svantaggiati, per ciascuno degli anni dal 2021 al 2023*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 296, 14 December 2021.

Italian Government 2021e: Italian Government, Ministerial Decree 28 October 2021, No. 384, *Village coordination committee* [*Comitato di coordinamento borghi*]. https://media.beniculturali.it/mibac/files/boards/be78e33bc8ca0c99bff70aa174035096/DECRETI/ANNO%202021/DM%2028%20ottobre%202021%20rep%20384%20Comitato%20borghi-signed.pdf (last accessed: September 2025).

Italian Government 2022: Italian Government, Ministerial Decree 16 May 2022, *Preparation of the National Plan for the Redevelopment of Small Municipalities* [*Predisposizione del Piano nazionale per la riqualificazione dei piccoli comuni*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 167, 10 July 2022. https://www.gazzettaufficiale.it/eli/id/2022/07/19/22A04101/SG (last accessed: August 2025).

Ministry for the Territorial Cohesion and the South 2021: Ministry for the Territorial Cohesion and the South, *Strategia nazionale per le Aree interne: definizione, obiettivi, strumenti e governance*, Rome 2021. https://www.mim.gov.it/documents/20182/890263/strategia_nazionale_aree_interne.pdf (last accessed: August 2025).

Ministry for the Territorial Cohesion and the South 2025: Ministry for the Territorial Cohesion and the South, *Piano Strategico Nazionale delle Aree Interne*, 2025. https://politichecoesione.governo.it/media/jhld12qn/psnai_finale_30072025_clean_ministro.pdf (last accessed: August 2025).

MiBACT 2016: MiBACT – Ministry of Cultural Heritage and Tourism, Directive 2 December 2016, No. 555, *2017. Year of the Italian Historic Villages* [*2017. Anno dei Borghi italiani*].

MiBACT 2017: MiBACT – Ministry of Cultural Heritage and Tourism, *Strategic Plan for Tourism 2017–2022: "* [*Piano Strategico del Turismo 2017–2022*], MiBACT, Rome 2017. https://distrettocostadamalfi.it/wp-content/uploads/2022/01/PIANO-STRATEGICO-di-SVILUPPO-del-TURISMO-17-febbraio-2017.pdf (last accessed: August 2025).

MiC - Ministry of Culture 2021: MiC – Ministry of Culture, *Guidelines on the implementation methods of intervention 2.1 "Attractiveness of villages", M1C3 tourism and culture of the National Recovery and Resilience Plan* [*Linee di indirizzo sulle modalità attuative dell'intervento 2.1 "Attrattività dei borghi", M1C3 turismo e cultura del Piano Nazionale di Ripresa e Resilienza*], 2021. https://media.beniculturali.it/mibac/files/boards/be78e33bc8ca0c99bff70aa174035096/PDF/Avvisi/Borghi/Linee%20di%20indirizzo%20Investimento%202.1-Attrattivita%20Borghi.pdf (last accessed: September 2025).

Region of Apulia 2013: Region of Apulia, Law 17 December 2013, No. 44, *Provisions for the restoration, protection, and enhancement of the most beautiful villages of Italy in Apulia* [*Disposizioni per il recupero, la tutela e la valorizzazione dei borghi più belli d'Italia in Puglia*], in «Bollettino Ufficiale della Regione Puglia», No. 169, 20 December 2013. https://trasparenza.regione.puglia.it/sites/default/files/provvedimento_amministrativo/44848_44_17-12-2013_L_44_17_12_2013.pdf

Space Engagers 2020: Space Engagers, *The Town Centre Living Initiative. Six Pilot Towns: Synthesis Report*, 2020. https://assets.gov.ie/static/documents/the-town-centre-living-initiative.pdf (last accessed: September 2025).

*Territorial Agenda 2030. A Future for All Places* 2020: *Territorial Agenda 2030. A Future for All Places*, 2020. https://territorialagenda.eu/wp-content/uploads/TA2030_jun2021_en.pdf (last accessed: August 2025).

Vlaamse Landmaatschappij 2021: Vlaamse Landmaatschappij, *Versterken omgevingskwaliteit en vitaliteit van het platteland door samenwerking. Wegwijzer voor het indienen van een subsidiedossier via het plattelandsloket*, 2021. https://www.vlm.be/nl/SiteCollectionDocuments/Platteland/Omgevingskwaliteit_samenwerking_reglement_2021.pdf (last accessed: August 2025).

*Sardinian context*

### Online resources

Aru *et al.* 1991: A. Aru., P. Baldaccini, A. Vacca, *Carta dei suoli della Sardegna in scala 1:250.000*, 1991. https://www.sardegnaportalesuolo.it/opendata/carta-dei-suoli-della-sardegna-alla-scala-1250000.html (last accessed: June 2025)

Autonomous Region of Sardinia 2006a: Autonomous Region of Sardinia, *Piano Paesaggistico Regionale*, 2006. https://www.sardegnaterritorio.it/paesaggio/pianopaesaggistico2006.html (last accessed: September 2025).

Autonomous Region of Sardinia 2008a: Autonomous Region of Sardinia, *Inserimento nelle cartografie e nel dispositivo del piano delle riperimetrazioni dei centri di antica e prima formazione già decretata ai sensi della L.R. n.13/2008*, 2008. http://sardegnaterritorio.it/j/v/1293?s=274011&v=2&c=12580&t=1 (last accessed: September 2025).

Autonomous Region of Sardinia 2012: Autonomous Region of Sardinia, *Verifiche dei centri matrice*, last update 2012. https://www.sardegnaterritorio.it/j/v/1123?s=6&v=9&c=7343&na=1&n=10 (last accessed: September 2025).

Autonomous Region of Sardinia 2014: Autonomous Region of Sardinia, *Programmazione Territoriale*, 2014. https://old.sardegnaprogrammazione.it/index.php?xsl=1227&s=35&v=9&c=14710&es=6603&na=1&n=10&ni=1 (last accessed: September 2025).

Autonomous Region of Sardinia 2025b: Autonomous Region of Sardinia, *Le nuove Aree SNAI della Regione Sardegna per il ciclo di programmazione 2021-27*, last updated 2025. https://old.sardegnaprogrammazione.it/index.php?xsl=1384&s=438186&v=2&c=7455&vd=1 (last accessed: September 2025).

*eBiddas*, n.d.: *eBiddas*, n.d. https://ebiddas.geonue.com/ (last accessed: September 2025).

Italian Government n.d.: Italian Government, *Gennargentu - Mandrolisai,* n.d. https://politichecoesione.governo.it/it/politica-di-coesione/strategie-tematiche-e-territoriali/strategie-territoriali/strategia-nazionale-aree-interne-snai/le-aree-interne-2014-2020/strategie-darea/regioni-del-sud/regione-sardegna/gennargentu-mandrolisai/ (last accessed: September 2025).

Municipality of Cagliari 2025: Municipality of Cagliari, *Autorizzazione paesaggistica*, last update 2025. https://www.comune.cagliari.it/portale/page/it/autorizzazioni_paesaggistiche?contentId=SRV10224 (last accessed: September 2025).

Municipality of Ulassai 2023: Municipality of Ulassai, *Ulassai e il PNRR*, 2023. https://www.comune.ulassai.nu.it/it/novita/page/ulassai-e-il-pnrr (last accessed: September 2025).

Unione di comuni "Alta Marmilla", n.d.: Unione di comuni "Alta Marmilla", n.d. https://unionecomunialtamarmilla.it/contenuti/1723602/ruralab-ecosistema-innovazione-rurale (last accessed: September 2025).

### Bibliography

Atzeni *et al.* 2022: C. Atzeni, A. M. Colavitti, S. Cadoni, A. Floris, F. Marras, S. Serra, *Cross-Disciplinary Approaches to the Regeneration of Minor Historical Centers: The Case of Mogoro in Sardinia*, in «Sustainability», 14 (2022), pp. 2–28.

Brundu 2022: B. Brundu, *Le potenzialità delle aree interne in Sardegna. Una breve riflessione dei nuovi percorsi intrapresi dalla SNAI nei territori dell'Alta Marmilla e del Gennargentu Mandrolisai*, in S. Battino (ed.), *Il turismo per lo sviluppo delle aree interne. Esperienze di rigenerazione territoriale*, EUT Edizioni Università di Trieste, Trieste 2022, pp. 51–61.

Cannas *et al.* 2017: I. Cannas, S. Curreli, D. Ruggieri, *Una analisi comparativa tra strategie di sviluppo e tutela dei centri minori in Sardegna*, in *Urbanistica E/È Azione Pubblica. La Responsabilità Della Proposta*, Proceedings of the XX National Conference SIU (Rome, June 2017), Planum Publisher, Rome-Milan 2017, pp. 461–469.

Cocco *et al.* 2016: F. Cocco, N. Fenu, M. Lecis Cocco-Ortu, *Spopolamento in Sardegna. Questioni di futuro*, in F. Cocco, N. Fenu, M. Lecis Cocco-Ortu (eds.) SPOP. Istantanea dello spopolamento in Sardegna, LetteraVentidue, Siracusa 2016, pp. 16–23.

Colavitti, Serra 2017: A.M. Colavitti, S. Serra, *Historical center planning in Sardinia: the replacement of the inconsistent building fabric for the renovation of the historic landscape*, in «Valori e Valutazioni», 19 (2017), pp. 79–89. https://siev.org/wp-content/uploads/2020/02/19_07_Colavitti-and-Serra_Eng.pdf (last accessed: August 2025).

Leone, Zoppi 2014: F. Leone, C. Zoppi, *La pianificazione dei Centri storici in Sardegna: una visione strategica per la redazione dei piani particolareggiati nel contesto del Piano paesaggistico regionale*, in *L'urbanistica italiana nel mondo*, Proceedings of the XVII National Conference SIU (Milan, May 2014), Planum Publisher, Rome-Milan 2014, pp. 1016–1024.

Leone, Zoppi 2016a: F. Leone, C. Zoppi, *Planning for the Conservation of Historic Districts in Sardinia, Italy. Strategic and Energy Efficiency-Related Issues, and an Ontological Approach Concerning a Small Town*, in R. Papa, R. Fistola (eds.), *Smart Energy in the Smart City. Urban Planning for a Sustainable Future*, Springer, Switzerland 2016.

Ortu 2009: G.G. Ortu, *Le aree storiche della Sardegna: costruzioni territoriali e civili*, in G.G. Ortu, A. Sanna (eds.), *Atlante delle culture costruttive in Sardegna. Le geografie dell'abitare*, DEI Tipografia del Genio Civile – Regione Autonoma della Sardegna, Cagliari 2009, pp. 1–70.

Pischedda, Vagnarelli 2020: S.E. Pischedda, T. Vagnarelli, *The depopulation phenomenon in Northern Sardinia: strategies and solutions for new ways of living*, in A.M. Oteri, G. Scamardì (eds.), *One needs a town. Studies and perspectives for abandoned or depopulated small towns*, «ArcHistoR EXTRA», 7, 13 (2020), pp. 1440–1457.

Renoldi, McComas 2023: S. Renoldi, J.S.M. McComas, *Le aree SNAI e il PNRR in Sardegna: sfide e opportunità in ambito turistico per il ciclo di programmazione 2021-2027*, in «TuRiStIcA», 31 (2023), 4, pp. 107–145.

Sanna 2009a: A. Sanna, *Il nuovo progetto per i centri storici, tra conservazione e modificazione*, in G.G. Ortu, A. Sanna (eds.), *Atlante delle culture costruttive in Sardegna. Approfondimenti*, DEI Tipografia del Genio Civile – Regione Autonoma della Sardegna, Cagliari 2009, pp. 10–12.

### Laws, Regulations, Reports and Guidelines

Autonomous Region of Sardinia 1984: Autonomous Region of Sardinia, Decree of the Regional Minister for Local Authorities, Finance, and Urban Planning 20 December 1983, No. 2266, *Regulation of the constraints and relationships governing the development of new urban planning instruments and the revision of existing ones in the municipalities of Sardinia* [*Disciplina dei limiti e*

*dei rapporti relativi alla formazione di nuovi strumenti urbanistici ed alla revisione di quelli esistenti nei Comuni della Sardegna*], in «Bollettino Ufficiale della Regione Autonoma della Sardegna», No. 6, 10 February 1984. https://www.comune.bono.ss.it/docs/normativa/d_a_22_dicembre_1983_n.%202266u%20-%20decreto%20floris.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 1998: Autonomous Region of Sardinia, Regional Law 13 October 1998, No. 29, *Protection and enhancement of Sardinia's historic centres* [*Tutela e valorizzazione dei centri storici della Sardegna*], in «Bollettino Ufficiale della Regione Autonoma della Sardegna», No. 31, 19 October 1998. https://www.edizioneuropee.it/law/html/137/sa4_01_035.html (last accessed: September 2025).

Autonomous Region of Sardinia 2006b: Autonomous Region of Sardinia, Regional Lancape Plan, *Scientific Committee Report* [*Piano Paesaggistico Regionale, Relazione Comitato Scientifico*], 2006. https://www.regione.sardegna.it/documenti/1_49_20051213120346.pdf (last accessed: August 2025).

Autonomous Region of Sardinia 2006c: Autonomous Region of Sardinia, *Regional Landscape Plan. General Technical Report* [*Piano Paesaggistico Regionale. Relazione Tecnica Generale*], 2006.

Autonomous Region of Sardinia 2006d: Autonomous Region of Sardinia, *Regional Landscape Plan. Technical Standards* [*Piano Paesaggistico Regionale. Norme tecniche di attuazione*], 2006. https://www.regione.sardegna.it/documenti/1_73_20060908134455.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 2007a: Autonomous Region of Sardinia, *Linee guida per l'adeguamento dei Piani Urbanistici Comunali al PPR e al PAI. Prima fase - Il riordino delle conoscenze. Principi e obiettivi,* 2007. https://www.sardegnaterritorio.it/documenti/6_83_20070612104158.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 2007b: Autonomous Region of Sardinia, *Implementation Guidelines of the Regional Landscape Plan* [*Indirizzi applicativi del Piano Paesaggistico Regionale*], Annex to Regional Government Resolution 20 March 2007, No. 11/17.

Autonomous Region of Sardinia 2008b: Autonomous Region of Sardinia, Regional Law 4 August 2008, No. 13, *Urgent provisions concerning landscape assets and the delimitation of historic centres and precautionary boundaries of landscape and identity-related assets* [*Norme urgenti in materia di beni paesaggistici e delimitazione dei centri storici e dei perimetri cautelari dei beni paesaggistici e identitari*], in «Bollettino Ufficiale della Regione Autonoma della Sardegna», No. 25, 7 August 2008. https://www.sardegnaterritorio.it/documenti/6_476_20220124170515.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 2009a: Autonomous Region of Sardinia, Regional Law 23 October 2009, No. 4, *Extraordinary provisions for supporting the economy through the relaunch of the construction sector and the promotion of strategically significant interventions and development programmes* [*Disposizioni straordinarie per il sostegno dell'economia mediante il rilancio del settore edilizio e per la promozione di interventi e programmi di valenza strategica per lo sviluppo*], in «Bollettino Ufficiale della Regione Autonoma della Sardegna», No. 35, 31 October 2009. https://www.sardegnaterritorio.it/documenti/6_532_20150612075457.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 2009b: Autonomous Region of Sardinia, *La tutela del paesaggio nei centri di antica e prima formazione. Linee guida. Gli spazi pubblici*, 2009. https://www.sardegnaterritorio.it/documenti/6_83_20090511112026.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 2009c: Autonomous Region of Sardinia, *La tutela del paesaggio nei centri di antica e prima formazione. Linee guida. Gli edifici*, 2009. https://www.sardegnaterritorio.it/documenti/6_83_20090504094922.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 2013a: Autonomous Region of Sardinia, *Piano Paesaggistico Regionale. Relazione dell'aggiornamento e revisione*, 2013. https://www.regione.sardegna.it/documenti/1_274_20131030205337.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 2013b: Autonomous Region of Sardinia, *Le politiche di riqualificazione urbana e recupero degli insediamenti storici in Sardegna*, TIEMME, Officine Grafiche, Assemini 2013. https://www.sardegnaterritorio.it/documenti/46_648_20161012115605.pdf (last accessed: September 2025).

Autonomous Region of Sardinia 2020: Autonomous Region of Sardinia, Regional Law 24 June 2020, No. 17, *Amendments to Regional Law No. 22 of 2019 concerning the extension of deadlines* [*Modifiche alla legge regionale n. 22 del 2019 in materia di proroga di termini*], in «Bollettino Ufficiale della Regione Autonoma della Sardegna», No. 36, 25 June 2020. https://www.legislazionetecnica.it/6479703/normativa-edilizia-appalti-professioni-tecniche-sicurezza-ambiente/l-r-sardegna-24-06-2020-n-17/proroga-piano-casa (last accessed: September 2025).

Autonomous Region of Sardinia 2021a: Autonomous Region of Sardinia, *Strategia Nazionale delle Aree Interne Programmazione 2021-2027. Dossier di candidatura della Regione Sardegna*, 2021.

FormezPA 2022: FormezPA, La Strategia Nazionale per le Aree Interne. Regione Autonoma della Sardegna. Programmazione 2021-27, 2022. https://politichecoesione.governo.it/media/3177/snai-dossier-regionale-sardegna.pdf (last accessed: October 2025).

Greenpeace 2024: Greenpeace, *L'eolico in Sardegna. Un'analisi del racconto sui media nel 2024*, 2024. https://www.greenpeace.org/static/planet4-italy-stateless/2025/02/6e388e6f-eolico-in-sardegna.pdf (last accessed: October 2025).

## *Traditional Architecture and Bioclimatic Features*

*General principles*

**Bibliography**

Aronin 1953: J. E. Aronin, *Climate and Architecture*, Reinhold, New York (USA) 1953.

Banham 1969: R. Banham, *Architecture of the Well-Tempered Environment*, The Architectural Press, London 1969.

Banham 1971: R. Banham, *Los Angeles: The Architecture of Four Ecologies,* Harper and Row, New York 1971.

Casanovas, Graus 2007: X. Casanovas, R. Graus, *Bioclimatic values in the rehabilitation of Traditional Mediterranean Architecture*, in RehabiMed Consortium (a cura di), *RehabiMed Method: Traditional*

*Mediterranean Architecture. II. Building Rehabilitation*, RehabiMed Consortium, Barcellona 2007, pp. 78–86.

Cetica 2004: P. A. Cetica, *L'architettura dei muri intelligenti. Esperienze di climatizzazione sostenibile nell'Ottocento*, Angelo Pontecorboli Editore, Firenze 2004.

Coch 1998: H. Coch, *Chapter 4. Bioclimatism in vernacular architecture*, in «Renewable and Sustainable Energy Reviews», II (1998), pp. 67-87.

Davoli 1993: P. Davoli, *Architettura senza impianti. Aspetti bioclimatici dell'architettura preindustriale*, Alinea, Firenze 1993.

De Bernardinis 2011: P. De Bernardinis, *Introduzione*, in M. Cirasa, *Recupero degli spazi aperti di relazione nei centri storici minori: aspetti bioclimatici e innovazione tecnologica*, Gangemi Editore, Roma 2011, pp. 9–11

Dehghani-Sanij 2022: A. Dehghani-Sanij, *Providing Thermal Comfort for Buildings' Inhabitants Through Natural Cooling and Ventilation Systems: Wind Towers*, in A. Sayigh (ed.), *Achieving Building Comfort by Natural Means. Innovative Renewable Energy*, Springer, Cham (Switzerland) 2022.

Fathy 1986: H. Fathy, *Natural Energy and Vernacular Architecture. Principles and Examples with Reference to Hot Arid Climates*, The United Nations University, Chicago 1986.

Givoni 1969: B. Givoni, *Man, Climate and Architecture*, Elsevier, Amsterdam/London/New York (Netherlands/UK/USA) 1969.

Guardigli 2018: L. Guardigli, *Edilizia e ambiente. Criteri e metodi per la valutazione della qualità ambientale degli edifici*, EdicomEdizioni, Roma 2018.

Hammond, Jones 2008: G.P. Hammond, C. I. Jones, *Embodied energy and carbon in construction materials*, in «Energy», Vol. 161, 2 (2008), pp. 87-98.

Kottek *et al.* 2006: M. Kottek, J. Grieser, C. Beck, B. Rudolf, F. Rubel, *World Map of the Köppen-Geiger climate classification updated*, in «Meteorol. Z.», 15 (2006), pp. 259–263.

Los 1990: S. Los, *Un programma regionalista per l'architettura*, in S. Los (a cura di), *Regionalismo dell'architettura*, Muzzio, Padova 1990.

Lucchi, Pracchi 2013: E. Lucchi, V. N. Pracchi (eds.), *Efficienza energetica e patrimonio costruito*, Maggioli, Santarcangelo di Romagna 2013.

Manzano-Agugliaro *et al.* 2015: F. Manzano-Agugliaro, F. G. Montoya, A. Sabio-Ortega. A. García-Cruz, *Review of bioclimatic architecture strategies for achieving thermal comfort*, in «Renewable and Sustainable Energy Reviews», 49 (2015), pp. 736–755.

Marta 2010: M. Marta, *Rischi e potenzialità ambientali per la città in crisi*, in «Semestrale di Studi e Ricerche di Geografia», XXII, 1 (2010), pp. 73–90.

McHarg 1971: I. L. McHarg, *Design with nature*, Doubleday/Natural History Press, New York 1971.

Olgyay 1981: V. Olgyay, *Progettare con il clima: un approccio bioclimatico al regionalismo architettonico*, italian translation by G. Mancuso, Muzzio Editore, Padova 1981 (original edition *Design with Climate*, Princeton University Press, Princeton 1963).

Oliver 1997: P. Oliver, *Encyclopedia of Vernacular Architecture of the World*, Cambridge University Press, Cambridge 1997.

Osman 2022: M. Osman, *Banham's Historical Ecology*, in M. Benedikt, T. Rice, T. Saunders (a cura di), *Environmental Futures. Rethinking Architecture and the Ecological Turn*, University of Texas Press, Austin 2022, pp. 231-251.

Rudofsky 1964: B. Rudofsky, *Architecture Without Architects. A Short Introduction to Non-Pedigreed Architecture*, Doubleday & Company, New York 1964.

Zaffagnini 1993: M. Zaffagnini, *Progettare nel Tessuto Urbano*, Alinea Editrice, Firenze 1993.

*Sardinian context*

**Bibliography**

Achenza, Sanna 2000: M. Achenza, A. Sanna (ed.), *Abitare la terra*, Proceedings of the Conference (Villamassargia-Samassi, November 1998), Cagliari 2000.

Angioni, Sanna 1984: G. Angioni, A. Sanna, *Sardegna*, Laterza, Roma 1984.

Baldacci 1952: O. Baldacci, *La casa rurale in Sardegna*, Centro di Studi per la Geografia Etnologica, Firenze 1952.

Baldassarre 1843: L. Baldassarre, *Cenni sulla Sardegna*, Schiepatti, Torino 1843.

Cannas, Desogus 2013: L.G.F. Cannas, G. Desogus, *Bioclimatic comparative analysis in vernacular architecture: two Sardinia examples*, in Proceedings of the International Conference CIAV 2013 – 7°ATP Versus, *Vernacular Heritage and Earthen Architecture* (Vila Nova de Cerveira, October 2013), pp. 501-506.

Desogus *et al.* 2016: G. Desogus, L.G.F. Cannas, A. Sanna, *Bioclimatic lessons from Mediterranean vernacular architecture: The Sardinian case study*, in «Energy and Buildings», CXXIX (2016), pp. 574–588.

Giannattasio 2021: C. Giannattasio, *The art of traditional masonry construction in Sardinia. Knowledge Preservation Recovery*, Gangemi Editore, Roma 2021.

Sanna 2009b: A. Sanna, *Forme, culture e strutture dell'insediamento: Il luogo e il progetto*, in G.G. Ortu, A. Sanna (eds.), *Atlante delle culture costruttive in Sardegna. Le geografie dell'abitare*, DEI Tipografia del Genio Civile – Regione Autonoma della Sardegna, Cagliari 2009, pp. 83–112.

Sanna, Atzeni 2009: A. Sanna, C. Atzeni (eds.), *I manuali del recupero dei centri storici della Sardegna. Architettura in terra cruda dei Campidani, del Cixerri e del Sarrabus*, dei Tipografia del Genio Civile, Università degli Studi di Cagliari – Dipartimento di Architettura, Regione Autonoma della Sardegna, 2009.

Sanna, Cuboni 2009: A. Sanna, F. Cuboni (eds.), *I manuali del recupero dei centri storici della Sardegna. Architettura in pietra delle Barbagie, dell'Ogliastra, del Nuorese e delle Baronie*, dei Tipografia del Genio Civile, Università degli Studi di Cagliari – Dipartimento di Architettura, Regione Autonoma della Sardegna, 2009.

**Laws, Regulations, Reports and Guidelines**

ISPRA 2015: ISPRA – Istituto Superiore per la Protezione e la Ricerca Ambientale, *Il Sistema Carta della Natura della Sardegna*, 2015. https://www.isprambiente.gov.it/files/pubblicazioni/rapporti/R_222_15.pdf (last accessed: October 2025.

Municipality of Villasalto 2015: Municipality of Villasalto, *Piano particolareggiato per il centro*

*storico*, 2015.

***Environmental Challenges and Sustainability of Architecture and Cultural Heritage***

**Online resources**

European Environment Agency 2024: European Environment Agency, *Circular economy*, 2024. https://www.eea.europa.eu/en/topics/in-depth/circular-economy (last accessed: September 2025).

IPCC 2025: IPCC – Intergovernmental Panel on Climate Change, *History of the IPCC*, last update: 2025. https://www.ipcc.ch/about/history/ (last accessed: September 2025).

ISPRA 2024: ISPRA, *Consumo di suolo, sempre più ridotto "l'effetto spugna": un costo da 400 milioni di euro all'anno*, 2024. https://www.isprambiente.gov.it/it/istituto-informa/comunicati-stampa/anno-2024/consumo-di-suolo (last accessed: September 2025).

Jet Propulsion Laboratory 2008: Jet Propulsion Laboratory, *A Brief History of Carbon Dioxide Measurements*, 2008. https://airs.jpl.nasa.gov/news/111/a-brief-history-of-carbon-dioxide-measurements/ (last accessed: September 2025).

UNESCO 2019a: UNESCO, *Culture - key to rural-urban development of historic towns*, 2019. https://www.unesco.org/en/articles/culture-key-rural-urban-development-historic-towns (last accessed: September 2025).

UNESCO 2019b: UNESCO – United Nations Educational, Scientific and Cultural Organization, *Sviluppo urbano sostenibile*, 2019. https://www.unesco.it/it/temi-in-evidenza/cultura/sviluppo-urbano-sostenibile/#:~:text=sfide%20alla%20conservazione%20delle%20citt%C3%A0,pubblicato%20dall%E2%80%99UNESCO%20in%2035%20anni (last accessed: September 2025).

United Nations n.d.a: United Nations, *Millennium Development Goals*, n.d. https://www.un.org/millenniumgoals/ (last accessed: September 2025).

United Nations 2025: United Nations, *Goal 11: Make cities inclusive, safe, resilient and sustainable*, last update: 2025. https://www.un.org/sustainabledevelopment/cities/

UNEP - United Nations Environment Programme 2024: UNEP – United Nations Environment Programme, *Global Status Report for Buildings and Construction*, 2024. https://www.unep.org/resources/report/global-status-report-buildings-and-construction (last accessed: September 2025).

**Bibliography**

Aliverti 2010: L. Aliverti, *L'efficienza energetica e la compatibilità architettonica e paesaggistica nella conservazione dell'edilizia rurale tradizionale*, unpublished manuscript, Fondazione F.lli Confalonieri, maggio 2010.

Armstrong *et al.* 2023: G. Armstrong, S. Wilkinson, E. J. Cilliers, *A framework for sustainable adaptive reuse: understanding vacancy and underuse in existing urban buildings*, in «Frontiers in Sustainable Cities», 5 (2023).

Auclair, Fairclough 2015: E. Auclair, G. Fairclough, *Living between past and future: an introduction to heritage and cultural sustainability*, in E. Auclair, G. Fairclough (eds.), *Theory and Practice in Heritage and Sustainability: Between past and future*, Routledge, Abingdon/New York (UK/USA) 2015.

Bassas *et al.* 2020: E.C. Bassas, J. Patterson, P. Jones, *A review of the evolution of green residential architecture*, in «Renewable and Sustainable Energy Reviews», 125 (2020), article n. 109796.

Battisti 2015: A. Battisti, *Revitalization and refurbishment of minor historical centers in the Mediterranean*, in A. Sayigh (a cura di), *Mediterranean green buildings and renewable energy, Proceedings of the World Renewable Energy Network's Med Green Forum 2015 (Florence, 26–28 August 2015)*, Springer, pp. 235–244.

Benjamin 2008: W. Benjamin, *The Work of Art in the Age of Its Technological Reproducibility*, in M. W. Jennings, B. Doherty, T. Y. Levin, *The Work of Art in the Age of Its Technological Reproducibility, and Other Writings on Media*, The Belknap Press of Harvard University Press, Cambridge/London (USA/UK) 2008, pp. 19–55. https://monoskop.org/images/6/6d/Benjamin_Walter_1936_2008_The_Work_of_Art_in_the_Age_of_Its_Technological_Reproducibility_Second_Version.pdf (last accessed: September 2025).

Brenna 2013: S. Brenna, *Fifty years after the failed "Sullo" reform: The strange defeat of public urbanism*, in «Plurimondi», Vol. VI, 13 (2013), pp. 23-33.

Bullen 2011: P.A. Bullen, *Adaptive reuse of heritage buildings: Sustaining an icon or eyesore*, in L. Ruddock, P. Chynoweth, C. Egbu, M. Sutrisna, A. Parsa (eds.), *COBRA 2011*, Proceedings of the Conference *RICS Construction and Property Conference* (Salford, September 2011), Royal Institution of Chartered Surveyors, Salford 2011, pp. 1652-1662.

Conejos *et al.* 2016: S. Conejos, C. Langston, E. H. W. Chan, M. Y. L. Chew, *Governance of heritage buildings: Australian regulatory barriers to adaptive reuse*, in «Building Research & Information», Vol. 44, 5-6 (2016), pp. 507-519.

Cremaschi 1990: M. Cremaschi, *L'abusivismo meridionale: realtà e rappresentazione*, in «Meridiana», n. 9 (1990), pp. 127–153.

Della Torre 1999: S. Della Torre, *"Manutenzione" o "Conservazione"? La sfida del passaggio dall'equilibrio al divenire*, in G. Biscontin, G. Driussi (eds.), *Ripensare alla manutenzione. Ricerche, progettazione, materiali, tecniche per la cura del costruito*, Proceedings of the XV Conference Scienza e Beni Culturali (Bressanone, luglio 1999), Arcadia Ricerche, Venezia 1999, pp. 71–80.

Della Torre 2023: S. Della Torre, *Coevolutionary Thinking put into Practice*, in «Intrecci. Prospettive di ricerca per il costruito storico», II (2023), 2, pp. 14-23.

Desogus 2018: G. Desogus, *Riqualificare, integrare, sostituire. Il miglioramento della prestazione energetica del patrimonio costruito*, EdicomEdizioni, Monfalcone 2018.

Douglas 2006: J. Douglas, *Building Adaptation*, Elsevier, Oxford/Burlington (UK/USA) 2006.

El Faouri, Sibley 2024: B. El Faouri, M. Sibley, *Balancing Social and Cultural Priorities in the UN 2030 Sustainable Development Goals (SDGs) for UNESCO World Heritage Cities*, in «Sustainability», 16 (2024), article n. 5833.

Fila *et al.* 2024: D. Fila, H. Fünfgeld, H. Dahlmann, *Climate change adaptation with limited resources: adaptive capacity and action in small- and medium-sized municipalities*, in «Environment, Development and Sustainability», 26 (2024), pp. 5607–5627.

Fiorini *et al.* 2017: L. Fiorini, F. Zullo, B. Romano, *Urban development of the coastal system of the*

*Italian largest islands: Sicily and Sardinia*, in «Ocean & Coastal Management», 143 (2017), pp. 184-194.

Geddes 1915: P. Geddes, *Cities in Evolution: An Introduction to the Town Planning Movement and to the Study of Civics*, Williams & Norgate, London 1915.

Grosso *et al.* 2005: M. Grosso, G. Peretti, S. Piardi, G. Scudo, *Progettazione ecocompatibile dell'architettura*, Sistemi Editoriali, Napoli 2005.

Hartog 2007: F. Hartog, *Regimi di storicità. Presentismo e esperienze del tempo*, Sellerio, Palermo 2007.

Holling 1973: C. S. Holling, *Resilience and Stability of Ecological Systems*, in «Annual Review of Ecology and Systematics», 4 (1973), pp. 1-23.

Holling Goldberg 1971: C. S. Holling, M. A. Goldberg, *Ecology and Planning*, in «Journal of the American Institute of Planners», Vol. 37, 4 (1971), pp. 221-230.

Jacobs 1961: J. Jacobs, *The Death and Life of Great American Cities*, Random House, New York (USA) 1961.

Lehmann 2016: S. Lehmann, *Sustainable urbanism: towards a framework for quality and optimal density?*, in«Future Cities and Environment», 2 (2016), pp. 1–16.

Meadows 2008: D.H. Meadows, *Thinking in Systems: A Primer*, D. Wright (ed.), Sustainability Institute, Chelsea Green Publishing, White River Junction (VT) 2008.

Moser, Ekstrom 2010: S. C. Moser, J. A. Ekstrom, *A framework to diagnose barriers to climatechange adaptation*, in «PNAS», Vol. 107, 51 (2010), article n. 22027.

Norberg-Schulz 2006: C. Norberg-Schulz, *Genius Loci. Paesaggio, ambiente, architettura*, Marsilio, Venezia 2006 (ed. orig. 1980).

Pane 1928: R. Pane, *Tipi di architettura rustica in Napoli e nei Campi Flegrei*, in «Architettura e Arti Decorative», VII (1928), 12, pp. 529–543.

Pane 1959: R. Pane, *Città antiche edilizia nuova*, ESI, Napoli 1959.

Pane 1978a: R. Pane, *Il restauro dei beni ambientali, la Carta di Venezia e l'illusione tecnologica*, in *Il restauro in Italia e la Carta di Venezia*, Proceedings of the Conference ICOMOS (Napoli–Ravello, September 1977), in «Restauro», VI (1978), pp. 33–38.

Pane 1978b: R. Pane, *Urbanistica, architettura e restauro nell'attuale istanza psicologica,* in «Rivista di Psicologia Analitica», 18 (1978), pp. 13–25.

Ribeiro, Gonçalves 2019: P.J.G. Ribeiro, L.A.P.J. Gonçalves, *Urban resilience: A conceptual framework*, in «Sustainable Cities and Society», 50 (2019), article n. 101625.

Ridolfi *et al.* 2025: E. Ridolfi, M. Lucantonio, G. Di Baldassarre, B. Moccia, F. Napolitano, F. Russo, *The interplay between the urban development of Rome (Italy) and the Tiber River floods: A review of two millennia of socio-hydrological history*, in «Ambio», 54 (2025), pp. 198–210.

Romano *et al.* 2016: B. Romano, A. Marucci, F. Zullo, L. Fiorini, S. Ciabò, *Urban pressure and planning management on Italian coastal areas*, in C. Conese (ed.), *Monitoring of Mediterranean Coastal Areas: problems and Measurement Techniques*, Proceedings of the Sixth International Symposium (Livorno, September 2016), Firenze University Press, Firenze 2017.

Romano *et al.* 2020: B. Romano, L. Fiorini, A. Marucci, F. Zullo, *The Urbanization Run-Up in Italy: From a Qualitative Goal in the Boom Decades to the Present and Future Unsustainability*, in «Land», 9(2020), article n. 301.

Ruskin 1903: J. Ruskin, *The Seven Lamps of Architecture*, in E. T. Cook, A, Wedderburn (eds.), *The works of John Ruskin*, Vol. VIII, Longmans, Green, and Co., London 1903. http://lancaster.ac.uk/media/lancaster-university/content-assets/documents/ruskin/8SevenLampsofArchitecture.pdf (last accessed: September 2025).

Stabile 2017: F.R. Stabile, *Gustavo Giovannoni e la cultura dell'ambientismo*, in «Bollettino del Centro di Studi per la Storia dell'Architettura», I (2017), pp. 135–146.

Surian, Rinaldi 2003: N. Surian, M. Rinaldi, *Morphological response to river engineering and management in alluvial channels in Italy*, in «Geomorphology», Vol. 50, 4 (2003), pp. 307–326.

Vale, Campanella 2005: L. J. Vale and T. J. Campanella (eds.), *The Resilient City: How Modern Cities Recover from Disaster,* Oxford University Press, New York, 2005.

Vitiello 2012: M. Vitiello, *Prospettive ecologiche per il restauro. Riflessioni intorno ad alcune parole chiave*, FrancoAngeli, Milano 2012.

Vittoria 1973: E. Vittoria, *Tecnologia, Progettazione, Architettura*, in «Casabella», n. 375 (1973), pp. 17–24.

Vittorini *et al.* 1978: M. Vittorini, F. Cusani, C. Gelormino, A. Dal Piaz, A. Miglionico, *Dallo spreco edilizio alla politica di recupero dell'esistente. Prospettive e limiti del piano decennale per la casa*, Guida Editori, Napoli 1978.

Wade, Visscher 2021: F. Wade, H. Visscher, *Retrofit at scale: accelerating capabilities for domestic building stocks*, in «Buildings and Cities», Vol. 2, 1 (2021), pp. 800-811.

Wolfson 2013: T. Wolfson, *The Competing Priorities of Energy Conservation and Indoor Air Quality in the United States,*: Joint Center for Housing Studies of Harvard University, Cambridge 2013 (JCHS Working Paper W13-4).

**Laws, Regulations, Reports and Guidelines**

Autonomous Region of Sardinia 2017: Autonomous Region of Sardinia, *Direttiva per lo svolgimento delle verifiche di sicurezza dei canali tombati esistenti*, 2017. https://www.regione.sardegna.it/documenti/1_470_20171106110914.pdf (last accessed: October 2025).

Autonomous Region of Sardinia 2021b: Autonomous Region of Sardinia, *Piano di gestione del rischio di alluvioni. Secondo ciclo di pianificazione. Repertorio dei canali tombati*, 2021, 4 volumes.

Charney *et al.* 1979: J. G. Charney, A. Arakawa, D. J. Baker, B. Bolin, R. E. Dickinson, R. M. Goody, C. E. Leith, H. M. Stommel, C. I. Wunsch, *Carbon Dioxide and Climate. A Scientific Assessment*, National Academy of Sciences, Washinghton D.C. (USA) 1979. https://geosci.uchicago.edu/~archer/warming_papers/charney.1979.report.pdf (last accessed: September 2025).

Council of Europe 1972: Council of Europe, *European Soil Charter*, Strasbourg 1972. https://rm.coe.int/european-soil-charter/168067e296 (last accessed: June 2025).

Council of Europe 1975: Council of Europe, *European Charter of the Architectural Heritage (Amsterdam Charter)*, Amsterdam 1975. https://rm.coe.int/09000016807aac18 (last accessed: June 2025).

Council of Europe 2014: Council of Europe, *Council conclusions of 21 May 2014 on cultural heritage as a strategic resource for a sustainable Europe*, 2014. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014XG0614(08) (last accessed: September 2025).

Crowe *et al.* 2023: P. Crowe, I. de Sena, K. Madhu, J. Lopez Pelayo, *Heritage as an integral dimension of NEB and Green Deal. HeritACT Deriverable 2.1*, 2023. https://static1.squarespace.com/static/642b7dc3227d62555165139d/t/65b8c952d268863e9963096a/1706608985223/%5BHeritACT%5D_%5BWP2%5D_%5BD2.1%5D_%5Bv1.0%5D_%5B30062023%5D.pdf (last accessed: September 2025).

Direzione Regionale per i beni culturali e paesaggistici della Sardegna 2005: Direzione Regionale per i beni culturali e paesaggistici della Sardegna, *Progetto di ricerca Metodologie per la progettazione sostenibile del paesaggio. Rapporto finale. Linee guida per il progetto sostenibile del paesaggio rurale regionale*, 2005. https://sardegna.cultura.gov.it/wp-content/uploads/2024/02/Consistenza-del-paesaggio-rurale-in-Sardegna.pdf (last accessed: September 2025).

Duxbury *et al.* 2016: N. Duxbury, J. Hosagrahar, J. Pascual, *Why must culture be at the heart of sustainable urban development?*, Committee on Culture of United Cities and Local Governments (UCLG), 2016.

European Commission 1994: European Commission, *Charter of European Cities & Towns Towards Sustainability (Aalborg Charter),* Aalborg 1994. https://sustainablecities.eu/fileadmin/repository/Aalborg_Charter/Aalborg_Charter_English.pdf (last accessed: September 2025).

European Union 2007: European Union, *Leipzig Charter on Sustainable European Cities*, Leipzig 2007. https://territorialagenda.eu/wp-content/uploads/leipzig_charter_2007.pdf (last accessed: August 2025).

Heaphy *et al.* 2025: L. Heaphy, P. Crowe, C. Reddy, R. Abu Hilal, L. Reid-Powell, G. Vargas Castro, H. Vora, *Town Revitalisation through the Integration of Vacant Buildings into the Circular Economy: Final Report,* 2025.

ICOMOS - International Council of Monuments and Sites 2019: ICOMOS, *The Future of Our Pasts: Engaging Cultural Heritage in Climate Action*, 2019. https://publ.icomos.org/publicomos/jlbSai?html=Bur&base=technica&ref=43205&file=1885.pdf&path=CCHWG_final_print.pdf (last accessed: September 2025).

ICOMOS 2020: ICOMOS, *Resolution 20GA/15 - Cultural Heritage and the Climate Emergency*, 20th General Assembly, 2020. https://www.icomos.org/images/DOCUMENTS/Secretariat/2020/Cultural_Heritage_and_the_Climate_Emergency-Resolution_20GA_15_.pdf (last accessed: September 2025).

ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale 2013: ISPRA, *Pericolosità ambientale*, in *Tematiche in primo piano. Annuario dei dati ambientali*, 2013 https://www.isprambiente.gov.it/files/pubblicazioni/statoambiente/tematiche2013/8_Pericolositambientale.pdf (last accessed: September 2025).

Italian Chamber of Deputies 2022: Italian Chamber of Deputies, *Dossier di documentazione storica. La frana di Agrigento del 19 luglio 1966. Atti e documenti*, 2022. https://biblioteca.camera.it/application/xmanager/projects/biblioteca/attachments/documentazione/pdfs/000/000/013/DDS18007_online_prot.pdf (last accessed: September 2025).

Italian Government 1948: Italian Government, *La Costituzione della Repubblica Italiana*, 1948. https://www.senato.it/istituzione/la-costituzione (last accessed: September 2025).

Millennium Ecosystem Assessment 2005: Millennium Ecosystem Assessment, *Ecosystems and Human Well-Being: Synthesis*, Island Press, Washington (USA) 2005. https://www.millenniumassessment.org/documents/document.356.aspx.pdf (last accessed: September 2025).

Pianezze 2012: F. Pianezze, *L'obiettivo del miglioramento dell'efficienza energetica nel processo di conservazione del costruito storico*, Politecnico di Milano, Mantova 2012. https://www.politesi.polimi.it/retrieve/a81cb059-f336-616b-e053-1605fe0a889a/2012_03_PhD_Pianezze.pdf (last accessed: September 2025).

UNEP 2009: UNEP – United Nations Environment Programme, *Buildings and Climate Change: Summary for Decision-Makers*, Paris 2009. https://www.uncclearn.org/wp-content/uploads/library/unep207.pdf (last accessed: September 2025).

UNESCO 1954: UNESCO, *Convention for the Protection of Cultural Property in the Event of Armed Conflict (The Hague Convention)*, The Hague 1954. https://unesdoc.unesco.org/ark:/48223/pf0000187580 (last accessed: June 2025).

UNESCO 1962: UNESCO, *Recommendation concerning the Safeguarding of Beauty and Character of Landscapes and Sites*, Paris 1962. https://www.unesco.org/en/legal-affairs/recommendation-concerning-safeguarding-beauty-and-character-landscapes-and-sites#:~:text=For%20the%20purpose%20of%20this,cultural%20or%20aesthetic%20interest%20or (last accessed: June 2025).

UNESCO 1972: UNESCO, *Convention concerning the Protection of the World Cultural and Natural Heritage*, Paris 1972. https://whc.unesco.org/en/conventiontext/ (last accessed: June 2025).

UNESCO 1976: UNESCO, *Recommendation concerning the Safeguarding and Contemporary Role of Historic Areas*, 1976. https://unesdoc.unesco.org/ark:/48223/pf0000114038.page=136 (last accessed: September 2025).

UNESCO 1982: UNESCO, *World Conference on Cultural Policies. Final report*, 1982. https://unesdoc.unesco.org/ark:/48223/pf0000052505 (last accessed: September 2025).

UNESCO 1996: UNESCO, *Our Creative Diversity. Report of the World Commission on Culture and Development*, 1996. https://unesdoc.unesco.org/ark:/48223/pf0000101651 (last accessed: September 2025).

UNESCO 2001: UNESCO, *Universal Declaration on Cultural Diversity,* 2001. https://www.ohchr.org/en/instruments-mechanisms/instruments/universal-declaration-cultural-diversity (last accessed: September 2025).

UNESCO 2005a: UNESCO, *Convention on the Protection and Promotion of the Diversity of Cultural Expression*, 2005. https://unesdoc.unesco.org/ark:/48223/pf0000142919 (last accessed: September 2025).

UNESCO 2011: UNESCO, *Recommendation on the Historic Urban Landscape*, 2011.

UNESCO 2016: UNESCO, *Culture Urban Future. Global Report on Culture for Sustainable Urban Development. Summary*, Paris 2016. https://unesdoc.unesco.org/ark:/48223/pf0000246291 (last accessed: August 2025).

UNESCO 2024: UNESCO, *Basic Texts of the 2003 Convention for the Safeguarding of the Intangible Cultural Heritage*, 2024. https://ich.unesco.org/doc/src/2003_Convention_Basic_Texts_2024_version_EN.pdf (last accessed: September 2025).

UCLG - United Cities and Local Governments 2004: UCLG – United Cities and Local Governments, *Agenda 21 for culture*, 2004. https://www.agenda21culture.net/sites/default/files/2025-05/ag21_en.pdf (last accessed: September 2025).

United Nations 1987: United Nations, *Report of the World Commission on Environment and Development. Our Common Future*, 1987.

United Nations 1992a: United Nations, *Agenda 21*, 1992. https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf (last accessed: September 2025).

United Nations 1992b: United Nations, *Report of the United Nations Conference on Environment and Development*, 1992. https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf (last accessed: September 2025).

United Nations 1996: United Nations, *Report of the United Nations Conference on Human Settlements (Habitat II)*, 1996. https://docs.un.org/en/A/CONF.165/14 (last accessed: September 2025).

United Nations 1997: United Nations, *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, 1997. https://unfccc.int/sites/default/files/resource/docs/cop3/l07a01.pdf (last accessed: September 2025).

United Nations 2015a: United Nations, *Transforming our world: the 2030 Agenda for Sustainable Development*, Resolution adopted by the General Assembly on 25 September 2015, 2015. https://docs.un.org/en/A/RES/70/1 (last accessed: September 2025).

United Nations 2015b: United Nations, *Transforming Our World: The 2030 Agenda for Sustainable Development*, 2015. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (last accessed: August 2025).

United Nations 2016a: United Nations, *Habitat III Issue Papers. 4 – Urban Culture and Heritage*, 2016. https://habitat3.org/wp-content/uploads/Habitat-III-Issue-Paper-4_Urban-Culture-and-Heritage-2.0.pdf#:~:text=%E2%80%A2%20Failures%20in%20urban%20planning,compact%2C%20inclusive%20and%20resilient%20cities (last accessed: September 2025).

United Nations 2016b: United Nations, *New Urban Agenda*, 2016. https://habitat3.org/wp-content/uploads/NUA-English.pdf (last accessed: September 2025).

***Community Involvement***

**Online resources**

Catacombe di Napoli 2022: Catacombe di Napoli, *Cooperativa La Paranza*, last update 2022. https://catacombedinapoli.it/it/about/ (last accessed: October 2025).

Città metropolitana di Roma Capitale n.d.: Città metropolitana di Roma Capitale, *Co-Roma. Principi identitari di una cooperativa*, n.d. https://pianostrategico.cittametropolitanaroma.it/buone-pratiche/co-roma (last accessed: October 2025).

European Union 2023: European Union, *New European Bauhaus Prizes. Green Axes and Squares of Bcn's Eixample*, 2023. https://prizes.new-european-bauhaus.europa.eu/application/38546 (last accessed: October 2025).

Fondazione Real Sito di Carditello n.d.: Fondazione Real Sito di Carditello, *Inclusion*, n.d. https://www.fondazionecarditello.org/new/en/inclusion/ (last accessed: October 2025).

**Bibliography**

Annunzi, Moruzzo 2006: I. Annunzi, R. Moruzzo, *La cultura valutativa condivisa nei processi partecipativi di sviluppo locale*, in *Report di valutazione generale, CIPA-AT Progetto PROAERE – Progetti agricoltura energie rinnovabili in Europa*, Programma Leonardo da Vinci, 2006.

Cerutti 2019: S. Cerutti, *Geografie perdute, storie ritrovate: percorsi di partecipazione e sviluppo locale nelle Terre di Mezzo*, in «Rivista geografica italiana», Vol. CXXVI, 126 (2019), pp. 57–80.

Chitty 2017: G. Chitty (ed.), *Heritage, Conservation and Communities: Engagement, participation and capacity building*, Routledge, Oxon (UK)/New York (USA) 2017.

Iaione *et al.* 2022: C. Iaione, E. De Nictolis, M. E. Santagati, *Participatory Governance of Culture and Cultural Heritage: Policy, Legal, Economic Insights From Italy*, in «Sustainable Cities», 4 (2022), article n. 777708.

de Luca *et al.* 2021: C. de Luca, J. López-Murcia, E. Conticelli, A. Santangelo, M. Perello, S. Tondelli, *Participatory Process for Regenerating Rural Areas through Heritage-Led Plans: The RURITAGE Community-Based Methodology*. Sustainability, Vol. 13, 9 (2021), article n. 5212.

Gross 2007: C. Gross, *Community perspectives of wind energy in Australia: The application of a justice and community fairness framework to increase social acceptance*, in «Energy Policy», Vol. 35, 5 (2007), pp. 2727–2736.

Leach *et al.* 1997: M. Leach, R. Mearns, I. Scoones, *Editorial: Community-Based Sustainable Development: Consensus or Conflict*, in «IDS Bulletin», 28 (1997), pp. 1–3.

Leone, Zoppi 2016b: F. Leone, C. Zoppi, *Participatory processes and spatial planning – The Regional Landscape Plan of Sardinia, Italy*, FrancoAngeli, Milan 2016.

Magnaghi 2010: A. Magnaghi (ed.), *Montespertoli. Le mappe di comunità per lo statuto del territorio*, Alinea, Firenze. 2010.

Masika, Joekes 1997: R. Masika, S. Joekes, *Environmentally Sustainable Development and Poverty: A Gender Analysis*, BRIDGE Report 52, Institute of Development Studies, Brighton 1997.

Popescu *et al.* 2022: C. R. N. Popescu, G. N. Popescu, C. Olaru, R. Gherghina, *Social Innovation, Circularity and Energy Transition for Environmental, Social and Governance (ESG) Practices—A Comprehensive Review*, in «Energies», 15 (2022), article n. 9028.

Ricoeur 2005: P. Ricoeur, *Percorsi di riconoscimento*, Raffaello Cortina, Milano 2005.

Rosetti *et al.* 2020: I. Rosetti, M. Jacobs, A. Pereira Roders, Heritage and Sustainability: A Review of Recent Literature and a Reflection on the Role of Participatory Heritage Practices in Sustainable Development, Volkskunde. Tijdschrift over De Cultuur Van Het Dagelijks Leven 2020, pp. 105–122.

Rosetti *et al.* 2022: I. Rosetti, M. Jacobs, A. Pereira Roders, *Heritage and Sustainability: Regulating Participatio*n, in «Sustainability», 14 (2022), article n. 1674.

Rosado-García *et al.* 2021: M. J. Rosado-García, R. Kubus, R. Argüelles-Bustillo, M. J. García-García, *A New European Bauhaus for a Culture of Transversality and Sustainability*, in «Sustainability», 13 (2021), article n. 11844.

Sen 1999: A. Sen, *Development as Freedom*, Oxford University Press, Oxford 1999.

Settis 2017: S. Settis, *Architettura e democrazia*, Einaudi, Torino 2017.

Sokka *et al.* 2021: S. Sokka, F. Badia, A. Kangas, F. Donato, *Governance of cultural heritage: towards participatory approaches*, in «European Journal of Cultural Management and Policy», 11 (2021), pp. 4–19.

Walker *et al.* 2004: C. S. B. Walker, R. Holling, S. R. Carpenter, A. Kinzig, *Resilience, Adaptability and Transformability in Social–ecological Systems*, in «Ecology and Society», 9 (2004), article n. 5.

Warburton 1998: D. Warburton (ed.) *Community and Sustainable Development: Participation in the Future*, Earthscan, London 1998.

Waterton, Watson2011: E. Waterton, S. Watson, *Heritage and community engagement: finding a new agenda*, in E. Waterton, S. Watson (eds.), *Heritage and Community Engagement: Collaboration or Contestation?*, Routledge, New York (USA) 2011, pp. 1–11.

Wilson 2012: G. A. Wilson, *Community Resilience and Environmental Transitions*, Earthscan, Oxon (UK) 2012.

Žuvela *et al.* 2023: A. Žuvela, M. Šveb Dragija, D. A. Jelincic, *Partnerships in Heritage Governance and Management: Review Study of Public–Civil, Public–Private and Public–Private–Community Partnerships*, in «Heritage», 6 (2023), pp. 6862–6880.

**Laws, Regulations, Reports and Guidelines**

Australia ICOMOS 1999: Australia ICOMOS, *The Australia ICOMOS Charter for Places of Cultural Significance [Burra Charter] 1999*, Burwood (Australia) 1999. https://australia.icomos.org/wp-content/uploads/BURRA_CHARTER.pdf (last accessed: October 2025).

Australia ICOMOS 2013: Australia ICOMOS, *The Burra Charter 2013: The Australia ICOMOS Charter for Places of Cultural Significance*, Burwood (Australia) 2013. https://australia.icomos.org/wp-content/uploads/The-Burra-Charter-2013-Adopted-31.10.2013.pdf (last accessed: October 2025).

Council of Europe 2005: Council of Europe, *Council of Europe Framework Convention on the Value of Cultural Heritage for Society*, in «Council of Europe Treaty Series», No. 199, Faro 2005. https://rm.coe.int/1680083746 (last accessed: September 2025).

EURICSE – European Research Institute on Cooperative and Social Enterprises 2022: EURICSE – European Research Institute on Cooperative and Social Enterprises, *Rapporto Comunità Intraprendenti*, Trento 2022. https://euricse.eu/wp-content/uploads/2022/10/Rapporto-Comunita%CC%80-Intraprendenti_editato-11_10_22.pdf (last accessed: October 2025).

European Court of Auditors 2010: European Court of Auditors, *Implementation of the LEADER approach for rural development,* Publications Office of the European Union, Luxembourg 2010. https://www.eca.europa.eu/lists/ecadocuments/sr10_05/sr10_05_en.pdf (last accessed: October 2025).

European Union 2018: European Union, *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources*, 2018. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001 (last accessed: October 2025).

ENRD n.d.: ENRD – European Network for Rural Development, *LEADER Toolkit: LEADER/CLLD explained, European Commission*, Brussels n.d. https://ec.europa.eu/enrd/sites/default/files/leader_clld-explained_en.pdf (last accessed: October 2025).

ICOMOS 2008: ICOMOS, UNESCO World Heritage Centre, *Québec Declaration on the "Spirit of Place"*, Paris 2008. https://whc.unesco.org/uploads/activities/documents/activity-646-2.pdf (last accessed: October 2025).

New European Bauhaus High-Level Round Table 2021: New European Bauhaus High-Level Round Table, New European Bauhaus: Concept Paper, European Commission, Brussels 2021. https://new-european-bauhaus.europa.eu/system/files/2021-07/2021-06-30_New_European_Bauhaus_Concept_Paper_HLRT_FINAL.pdf (last accessed: October 2025).

UNESCO World Heritage Centre 2005b: UNESCO World Heritage Centre, *Vienna Memorandum on "World Heritage and Contemporary Architecture – Managing the Historic Urban Landscape"*, Paris 2005. https://unesdoc.unesco.org/ark:/48223/pf0000140984 (last accessed: October 2025).

United Nations General Assembly 1948: United Nations General Assembly, *Universal Declaration of Human Rights*, Paris 1948.

***Effects and Impacts of Climate Change: Mediterranean Area and Sardinia***

*Mediterranean context*

**Online resources**

European Environment Agency 2012: European Environment Agency, *Increase in the number of combined tropical nights (minimum temperature exceeding 20 °C) and hot days (maximum temperature exceeding 35 °C) under present and future climate conditions*, 2012. https://www.eea.europa.eu/en/analysis/maps-and-charts/increase-in-the-number-of (last accessed: October 2025).

UNEP 2021: UNEP, *Climate change in the Mediterranean*, 2021. https://www.unep.org/unepmap/resources/factsheets/climate-change (last accessed: October 2025).

**Bibliography**

Collins *et al.* 2013: M. Collins, R. Knutti, J. Arblaster, J. L. Dufresne, T. Fichefet, P. Friedlingstein. X. Gao, W. J. Gutowski, T. Johns, G. Krinner, M. Shongwe, C. Tebaldi, A. J. Weaver, M. Wehner, *Long-term climate change: projections, commitments and irreversibility* in T. F. Stocker, D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, P. M. Midgley (eds.), *Climate Change 2013: The Physical Science Basis*, Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge 2013.

Davy *et al.* 2017: R. Davy, I. Esau, A. Chernokulsky, S. Outten, S. Zilitinkevich, *Diurnal asymmetry to the observed global warming*, in «International Journal of Climatology», Vol. XXXVII, 1 (2017), pp. 79–93.

Déqué *et al.* 2012: M. Déqué, S. Somot, E. Sánchez-Gómez, C. M. Goodess, D. Jacob, G. Lenderink, O. B. Christensen, *The spread amongst ENSEMBLES regional scenarios: regional climate models, driving general circulation models and interannual variability*, in «Climate Dynamics», 38 (2012), pp. 951–964.

García-Ruiz *et al.* 2011: J. M. García-Ruiz, J. I. López-Moreno, S. M. Vicente-Serrano, T. Lasanta-Martínez, S. Beguería, *Mediterranean water resources in a global change scenario*, in «Earth-Science Reviews», Vol. CV, 3-4 (2011), pp. 121–139.

Giorgi 2006: F. Giorgi, *Climate change hot-spots*, in «Geographical Research Letters», Vol. 33, 8 (2006), pp. 1–4.

Giorgi, Lionello 2008: F. Giorgi, P. Lionello, *Climate change projections for the Mediterranean region*, in «Global and Planetary Change», Vol. 63, 2-3 (2008), pp. 90–104.

Gualdi *et al.* 2013: S. Gualdi, S. Somot, W. May, S. Castellari, M. Déqué, M. Adani, V. Artale, A. Bellucci, J. S. Breitgand, A. Carillo, R. Cornes, A. Dell'Aquila, C. Dubois, D. Efthymiadis, A. Elizalde, L. Gimeno, C. M. Goodess, A. Harzallah, S. O. Krichak, F. G. Kuglitsch, C. G. Leckebusch, B. L'Hévéder, L. Li, P. Lionello, J. Luterbacher, A. Mariotti, A. Navarra, R. Nieto, K. M. Nissen, P. Oddo, P. Ruti, A. Sanna, G. Sannino, E. Scoccimarro, F. Sevault, M. V. Struglia, A. Toreti, U. Ulbrich, E. Xoplaki, *Future climate projections*, in A. Navarra, L. Tubiana (eds.), *Regional Assessment of Climate Change in the Mediterranean*, Springer, Dordrecht 2013, pp 53–118.

Hajat *et al.* 2002: S. Hajat, R.S. Kovats, R.W. Atkinson, A. Haines, *Impact of hot temperatures on death in London: a time series approach*, in «Journal of Epidemiology and Community Health», LVI (2002), pp. 367–372.

Iglesias *et al.* 2007: A. Iglesias, L. Garrote, F. Flores, M. Moneo, *Challenges to manage the risk of water scarcity and climate change in the Mediterranean*, in «Water Resources Management», Vol. XXI, 5 (2007), pp. 775–788.

Lazoglou 2024: G. Lazoglou, A. Papadopoulos-Zachos, P. Georgiades, G. Zittis, K. Velikou, E. M. Manios, C. Anagnostopoulou, *Identification of climate change hotspots in the Mediterranean*, in «Scientific Reports», XIV, 1 (2024), art. 29817.

Lionello *et al.* 2006: P. Lionello, P. Malanotte-Rizzoli, R. Boscolo, P. Alpert, V. Artale, L. Li, J. Luterbacher, W. May, R. Trigo, M. Tsimplis, U. Ulbrich, E. Xoplaki, *The Mediterranean Climate: An Overview of the Main Characteristics and Issues*, in «Developments in Earth & Environmental Sciences», 4 (2006), pp. 1–26.

Lionello, Scarascia 2018: P. Lionello, L. Scarascia, *The relation between climate change in the Mediterranean region and global warming*, in «Regional Environmental Change», 18 (2018), pp. 1481–1493.

Royé *et al.* 2021: D. Royé, F. Sera, A. Tobías, R. Lowe, A. Gasparrini, M. Pascal *et al.*, *Effects of hot nights on mortality in southern Europe*, in «Epidemiology», XXXII, 4 (2021), pp. 487–498.

Ulbrich *et al.* 2012: U. Ulbrich, P. Lionello, D. Belušić, J. Jacobeit, P. Knippertz, F.G. Kuglitsch, G. C. Leckebusch, J. Luterbacher, M. Maugeri, P. Maheras, K. M. Nissen, V. Pavan, J. G. Pinto, H. Saaroni, S. Seubert, A. Toreti, E. Xoplaki, B. Ziv, *Climate of the Mediterranean: synoptic patterns, temperature, precipitation, winds, and their extremes*, in P. Lionello (ed.), *The Climate of the Mediterranean Region. From the Past to the Future*, Elsevier, Amsterdam 2012, pp 301–346.

Ulbrich *et al.* 2013: U. Ulbrich, E. Xoplaki, S. Dobricic, R. García-Herrera, P. Lionello, M. Adani, M. Baldi, D. Barriopedro, P. Coccimiglio, G. Dalu, D. Efthymiadis, M. Gaetani, M. B. Galati, L. Gimeno, C. M. Goodess, P. D. Jones, F. G. Kuglitsch, G. C. Leckebusch, J. Luterbacher, M. Marcos-Moreno, A. Mariotti, R. Nieto, K. M. Nisse, D. Pettenuzzo, N. Pinardi, C. Pino, A. G. P. Shaw, P. Sousa, A. Toreti, R. M. Trigo, M. Tsimplis, *Past and current climate changes in the Mediterranean region*, in A. Navarra, L. Tubiana (eds.), *Regional Assessment of Climate Change in the Mediterranean*, Springer, Dordrecht 2013, pp 9–52.

Wang *et al.* 2017: K. Wang, Y. Li, Y. Wang, X. Yang, *On the asymmetry of the urban daily air temperature cycle*, in «Journal of Geophysical Research: Atmospheres», Vol. CXXII, 11 (2017), pp. 5625–5635.

Yavaşlı, Erlat 2018: D. D. Yavaşlı, E. Erlat, *The relation between climate change in the Mediterranean region and global warming*, in «Regional Environmental Change», 18 (2018), pp. 1481–1493.

**Laws, Regulations, Reports and Guidelines**

IPCC 2014: IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Geneva 2014. https://www.ipcc.ch/report/ar5/syr/ (last accessed: October 2025).

IPCC 2022: IPCC, *Climate Change 2022: Impacts, Adaptation and Vulnerability*, Cross-Chapter Paper 4: Mediterranean Region, Geneva 2022.

UNESCO 2025: UNESCO, *Climate change in Mediterranean World Heritage cities*, 2025. https://unesdoc.unesco.org/ark:/48223/pf0000394251 (last accessed: October 2025).

*Sardinian context*

**Online resources**

CMCC - Centro Euro-Mediterraneo sui Cambiamenti Climatici n.d.: CMCC – Centro Euro-Mediterraneo sui Cambiamenti Climatici, *Scenari climatici per l'Italia*, n.d. https://www.cmcc.it/it/scenari-climatici-per-litalia (last accessed: October 2025).

**Bibliography**

Cuevas-Wizner *et al.* 2024: R. Cuevas-Wizner, A. Ledda, B. Martín, E. Ortega, G. Calia, A. De Montis, *Mainstreaming Adaptation to Climate Changes: A Comparison between Sardinia, Italy and Valencia, Spain*, in «Sustainability», Vol. XVI, 16 (2024), art. 7099.

Ledda *et al.* 2020: A. Ledda, E. A. Di Cesare, G. Satta, G. Cocco, G. Calia, F. Arras, A. Congiu, E. Manca, A. De Montis, *Adaptation to Climate Change and Regional Planning: A Scrutiny of Sectoral Instruments*, in «Sustainability», Vol. XII, 9 (2020), art. 3804.

**Laws, Regulations, Reports and Guidelines**

Autonomous Region of Sardinia 2024a: Autonomous Region of Sardinia, *Strategia*

*Regionale di Adattamento ai Cambiamenti Climatici (SRACC) 2024*, adopted with Deliberation of the Regional Government no. 14/71 of 22 May 2024. https://portal.sardegnasira.it/documents/21213/201290/SRACC2024.pdf/88c09cce-a7fa-407a-8edb-aeb310f6a6a1(last accessed: October 2025).

## *Energy and historic buildings: legislation and contemporary challenges*

### Online resources

Associazione Elettrica Sarda 2025: Associazione Elettrica Sarda, *Ha sede a Macomer la più grande Comunità Energetica della Sardegna*, 2025. https://www.indipendenzaenergetica.com/2025/08/28/ha-sede-a-macomer-la-piu-grande-comunita-energetica-della-sardegna/ (last accessed: October 2025).

Autonomous Region of Sardinia 2024b: Autonomous Region of Sardinia, *Industria: avvio del catasto energetico degli edifici digitale dal 23 gennaio 2025. Assessore Cani, finalmente la Sardegna si conforma alla normativa e semplifica la procedura*, 2024. https://www.regione.sardegna.it/notizie/industria-avvio-del-catasto-energetico-degli-edifici-digitale-dal-23-gennaio-2025-assessore-cani-finalmente-la-sardegna-si-conforma-alla-normativa-e-semplifica-la-procedura (last accessed: October 2025).

Autonomous Region of Sardinia 2024c: Autonomous Region of Sardinia, *Programma Regionale Sardegna FESR 2021-2027. Priorità 3 Transizione verde - Obiettivo specifico Os2.i Promuovere l'efficienza energetica e ridurre le emissioni di gas a effetto serra - Azione 3.1.2 Sub Azione 3.1.2.a Interventi per l'efficientamento energetico di edifici e impianti pubblici - DGR n. 38/19 del 2.10.2024. FESR - Fondo Europeo di Sviluppo Regionale 2021-2027*, 2024. https://www.regione.sardegna.it/atti-bandi-archivi/atti-amministrativi/bandi/173288945363090 (last accessed: October 2025).

Autonomous Region of Sardinia 2025c: Autonomous Region of Sardinia, *Efficientamento energetico, 29 milioni alle PMI sarde: pubblicato il bando per richiedere i contributi a fondo perduto. L'assessore Cani: "Abbatterà in modo significativo i costi delle bollette"*, 2025. https://www.regione.sardegna.it/notizie/efficientamento-energetico-29-milioni-alle-pmi-sarde-pubblicato-il-bando (last accessed: October 2025).

Autonomous Region of Sardinia 2025d: Autonomous Region of Sardinia, *La Giunta approva le linee guida per l'intesa tra Regione Sardegna ed Enti Locali per la realizzazione di impianti FER in aree non idonee*, 2025. https://www.regione.sardegna.it/notizie/la-giunta-approva-le-linee-guida-per-l-intesa-tra-regione-sardegna-ed-enti-locali-per-la-realizzazione-di-impianti-fer-in-aree-non-idonee (last accessed: October 2025).

Autonomous Region of Sardinia 2025e: Autonomous Region of Sardinia, *La Giunta adotta il Piano di Individuazione delle Zone di Accelerazione Terrestri per gli Impianti a fonti rinnovabili. L'assessore Cani: "Rispettiamo le regole a tutela delle comunità". L'assessore Spanedda: "Il territorio lo programmiamo noi"*, 2025. https://www.regione.sardegna.it/notizie/la-giunta-adotta-il-piano-di-individuazione-delle-zone-di-accelerazione-terrestri-per-gli-impianti-a-fonti-rinnovabili-l-assessore-cani-rispettiamo-le-regole-a-tutela-delle-comunita-l-assessore-spanedda-il-territorio-lo-programmiamo-noi (last accessed: October 2025).

Autonomous Region of Sardinia 2025f: Autonomous Region of Sardinia, *Modifiche alla legge 20. L'assessore Spanedda: "La proposta di legge 146 chiarisce e completa la legge 20 del 2024, nell'interesse dei Comuni e dei cittadini sardi"*, 2025. https://www.regione.sardegna.it/notizie/modifiche-alla-legge-20-l-assessore-spanedda-la-proposta-di-legge-146-chi (last accessed: October 2025).

Autonomous Region of Sardinia 2025g: Autonomous Region of Sardinia, *Comunità energetiche rinnovabili, dalla Giunta nuovi contributi a comuni e altri enti per realizzare studi di fattibilità. L'assessore Cani: "Cresce l'interesse verso l'autoconsumo"*, 2025. https://www.regione.sardegna.it/notizie/comunita-energetiche-rinnovabili-dalla-giunta-nuovi-contributi-a-comuni-e-altri-enti-per-realizzare-studi-di-fattibilita-l-assessore-cani-cresce-l-interesse-verso-l-autoconsumo (last accessed: October 2025).

Cerema 2025: Cerema, *Energy Efficiency in Historic Buildings*, last updated 2025. https://eehb2026.sciencesconf.org/ (last accessed: October 2025).

CEN – European Committee for Standardization 2011: CEN – European Committee for Standardization, *EN 15978:2011. Sustainability of construction works: Assessment of environmental performance of buildings. Calculation method*, Brussels 2011. https://standards.iteh.ai/catalog/standards/cen/62c22cef-5666-4719-91f9-c21cb6aa0ab3/en-15978-2011?srsltid=AfmBOorYYJXDuYylBpGQfq6YJ3DopNbWiDdpkOeFu3iafNp_kLz4dv1C (last accessed: October 2025).

CMA – Competition & Markets Authority 2021: CMA - Competition & Markets Authority, *Guidance. Making environmental claims on goods and services*, 2021. https://www.gov.uk/government/publications/green-claims-code-making-environmental-claims/environmental-claims-on-goods-and-services (last accessed: October 2025).

DGNB - Deutsche Gesellschaft für Nachhaltiges Bauen n.d.: DGNB - Deutsche Gesellschaft für Nachhaltiges Bauen, *DGNB System for Districts. Planning and certifying sustainable districts*, n.d. https://www.dgnb.de/en/certification/districts (last accessed: October 2025).

European Commission n.d.c: European Commission, *The European Green Deal. Striving to be the first climate-neutral continent*, n.d. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (last accessed: October 2025).

European Commission n.d.d: European Commission, *Renovation Wave*, n.d. https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/renovation-wave_en (last accessed: October 2025).

European Commission n.d.e: European Commission, *Why a Covenant of Mayors?*, n.d. https://eu-mayors.ec.europa.eu/en/about (last accessed: October 2025).

European Commission n.d.f: European Commission, *Green claims*, n.d. https://environment.ec.europa.eu/topics/circular-economy/green-claims_en

European Commission 2016: European Commission, *Energy Efficiency for EU Historic Districts Sustainability*, last update 2016. https://cordis.europa.eu/project/id/314678/reporting (last accessed: October 2025).

European Commission 2020a: European Commission, *Questions and Answers on the Renovation Wave*, 2020. https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_1836 (last accessed: October 2025).

European Commission 2021b: European Commission, *Robust Internal Thermal Insulation of Historic Buildings*, 2021. https://culture.ec.europa.eu/funding/cultureu-funding-guide/case-

studies/robust-internal-thermal-insulation-of-historic-buildings (last accessed: October 2025).

European Council 2025: European Council, *Fit for 55*, last update 2025. https://www.consilium.europa.eu/en/policies/fit-for-55/ (last accessed: October 2025).

Global Covenant of Mayors for Climate & Energy n.d.: Global Covenant of Mayors for Climate & Energy, *Who we are*, n.d. https://www.globalcovenantofmayors.org/who-we-are/ (last accessed: October 2025).

Historic England 2025b: Historic England, *Risks of Energy Efficiency Interventions in Buildings of Traditional Construction*, 2025. https://historicengland.org.uk/advice/technical-advice/retrofit-and-energy-efficiency-in-historic-buildings/improving-energy-efficiency-through-mitigation/risks-of-energy-efficiency-interventions/ (last accessed: October 2025).

IEA SHC - International Energy Agengy Solar Heating and Cooling Programme n.d.: IEA SHC - International Energy Agengy Solar Heating and Cooling Programme n.d.: SHC - International Energy Agengy Solar Heating and Cooling Programme, *Renovating Historic Buildings Towards Zero Energy*, n.d. https://task59.iea-shc.org/ (last accessed: October 2025).

Mitrovic 2025: B. Mitrovic, *Architectural masquerades in the age of greenwashing*, Presentation in The Nordic Symposium on Beauty in Architecture (May 2025, Oslo, Norway). https://www.youtube.com/watch?v=HhbiQ29xcE0 (last accessed: October 2025).

United Nations n.d.b: United Nations, *Greenwashing – the deceptive tactics behind environmental claims*, n.d. https://www.un.org/en/climatechange/science/climate-issues/greenwashing (last accessed: October 2025).

U.S. Department of Energy 2025: U.S. Department of Energy, *End-of-Life Management for Solar Photovoltaics*, 2025. https://www.energy.gov/eere/solar/end-life-management-solar-photovoltaics (last accessed: October 2025).

**Bibliography**

Battisti 2016: A. Battisti, *Linee guida di indirizzo per l'efficienza energetica nel patrimonio culturale*, in «TECHNE», 12 (2016), pp. 65–73.

Barabino *et al.* 2023: E. Barabino, D. Fioriti, E. Guerrazzi, I. Mariuzzo, D. Poli, M. Raugi, E. Razaei, E. Schito, D. Thomopulos, *Energy Communities: A review on trends, energy system modelling, business models, and optimisation objectives*, in «Sustainable Energy, Grids and Networks», 36 (2023), article n. 101187.

Bouzarovski, Petrova 2015: S. Bouzarovski, S., Petrova, *A global perspective on domestic energy deprivation*, in «Energy Research & Social Science», 10 (2015), pp. 31–40.

Bruni, Papi 2019: A. Bruni, L. Papi, *Un modello tecnologico integrato per andare verso Smart@Pompei. Il progetto pilota MiBACT - CNR è replicabile anche in altri contesti*, in «Smart for city. Città storiche verso il futuro», 1 (2019), pp. 38– 43.

Buda *et al.* 2021: A. Buda, E.J. de Place Hansen, A. Rieser, E. Giancola, V.N. Pracchi, S. Mauri, V. Marincioni, V. Gori, K. Fouseki, C.S. Polo López, A. Lo Faro, A. Egusquiza, F. Haas, E. Leonardi, D. Herrera-Avellanosa, *Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach*, in «Sustainability», 13 (2021), article n. 2927.

Calama-González *et al.* 2022: C. M. Calama-González, P. Symonds, Á. L. León-Rodríguez, R. Suárez, *Optimal retrofit solutions considering thermal comfort and intervention costs for the Mediterranean social housing stock*, in «Energy and Buildings», 259 (2022), article n. 111915

Davide *et al.* 2025: M. Davide, J. Bastos, P. Bezzerra, G. Hernandez Moral, V. Palermo, *How to develop a Sustainable Energy and Climate Action Plan (SECAP) - Covenant of Mayors Guidebook - Main document*, Luxembourg, 2025.

Dehouche, Garner 2023: R. Garner, Z. Dehouche, *Optimal Design and Analysis of a Hybrid Hydrogen Energy Storage System for an Island-Based Renewable Energy Community*, in «Energies», Vol. 16, 21 (2023), article n. 7363.

De Jong *et al.* 2019: M. De Jong, T. Hoppe, N. Noori, *City Branding, Sustainable Urban Development and the Rentier State. How Do Qatar, Abu Dhabi and Dubai Present Themselves in the Age of Post Oil and Global Warming?*, in «Energies», Vol. 12, 9 (2019), article n. 1657.

Delmas, Cuerel Burbano 2011: M. A. Delmas, V. Cuerel Burbano, *The Drivers of Greenwashing*, in «California Management Review», Vol. 54, 1 (2011).

Filippidou, Jiménez Navarro 2019: F. Filippidou, J. P. Jiménez Navarro, *Achieving the cost-effective energy transformation of Europe's buildings*, Publications Office of the European Union, Luxembourg 2019.

Gönen, Kaplanoğlu 2019: C. Gönen, E. Kaplanoğlu, *Environmental and economic evaluation of solar panel wastes recycling*, in «Waste Manag. Res.», Vol. 37, 4 (2019), pp. 412-418.

Gori *et al.* 2021: V. Gori, V. Marincioni, H. Altamirano-Medin, *Retrofitting traditional buildings: a risk-management framework integrating energy and moisture*, in «Buildings and Cities», Vol. 2, 1 (2021), pp. 411–424.

Herrera-Avellanosa *et al.* 2024: D. Herrera-Avellanosa, J. Rose, K.E. Thomsen, F. Haas, G. Leijonhufvud, T. Brostrom, A. Troi, *Evaluating the Implementation of Energy Retrofits in Historic Buildings: A Demonstration of the Energy Conservation Potential and Lessons Learned for Upscaling. in* «Heritage», 7 (2024), pp. 997–1013.

Jordan, Kurtz 2012: D. C. Jordan, S. R. Kurtz, *Photovoltaic Degradation Rates — An Analytical Review*, in «Progress in Photovoltaics: Research and Applications», Vol. 21, 1 (2012), pp. 12-29.

Ju *et al.* 2023: Y. Ju, P. Hiltunen, J. Jokisalo, R. Kosonen, S. Syri, *Benefits through Space Heating and Thermal Storage with Demand Response Control for a District-Heated Office Building*, in «Buildings», Vol. 13, 10 (2023), article n. 2670.

Kyriazi 2019: E. Kyriazi, Façadism, *Building Renovation and theBoundaries of Authenticity,* in «Aesthetic Investigations», Vol. 2, 2 (2019), pp. 184-195.

Lidelöw *et al.* 2019: S. Lidelöw, T. Örn, A. Luciani, A. Rizzo, *Energy-efficiency measures for heritage buildings: A literature review*, in «Sustainable Cities and Society», 45 (2019), pp. 231–242.

Lucchi *et al.* 2020: E. Lucchi, C. S. Polo Lopez, G. Franco, *A conceptual framework on the integration of solar energy systems in heritage sites and buildings*, in «IOP Conf. Series: Materials Science and Engineering», 949 (2020), article n. 012113.

Lucchi *et al.* 2022: E. Lucchi, I. Dall'Orto, A. Peluchetti, L. Toledo, M. Pelle, C. Polo Lopez, G. Guazzi, *Photovoltaic technologies in historic buildings and protected areas: Comprehensive legislative framework in Italy and Switzerland*, in «Energy Policy», 161 (2022), article n. 112772.

Lucchi *et al.* 2023: E. Lucchi, J. Adami, A. E. Stawinoga, *Social acceptance of photovoltaic systems in heritage buildings and landscapes: Exploring barriers, benefits, drivers, and challenges for technical stakeholders in northern Italy*, in «Sustainable Energy Technologies and Assessments», 60 (2023), article n. 103544.

Lucchi, Pianezze 2013: E. Lucchi, F. Pianezze, *Quadro legislativo*, in E. Lucchi, V. N. Pracchi (eds.), *Efficienza energetica e patrimonio costruito*, Maggioli, Santarcangelo di Romagna 2013, pp. 11–33.

Magni *et al.* 2024: G.U. Magni, F. Battistelli, F. Trovalusci, D. Groppi, D. Astiaso Garcia, *How national policies influence energy community development across Europe? A review on societal, technical, and economical factors*, in «Energy Conversion and Management: X», 23 (2024), article n. 100624.

Mazzarella 2015: L. Mazzarella, *Energy retrofit of historic and existing buildings. The legislative and regulatory point of view*, in «Energy and Buildings», 95 (2015), pp. 23–31.

Neidig *et al.* 2022: J. Neidig, I. Anguelovski, A. Albaina, U. Pascual, *"We are the Green Capital": Navigating the political and sustainability fix narratives of urban greening*, in «Cities», 131 (2022), article n. 103999.

Mecca 2023: B. Mecca, *Assessing the sustainable development: A reviewof multi-criteria decision analysis for urbanand architectural sustainability, in Journal of Multi-Criteria Decision Analysis*, 30 (2023), pp. 203–218.

Plevoets 2021: B. Plevoets, *Juxtaposing inside and outside: façadism as a strategy for building adaptation*, in «The Journal of Architecture», 26 (2021), pp. 541-558.

Pracchi 2017: V. N. Pracchi, *In equilibrio tra soppesare e misurare: alcune riflessioni su sostenibilità ed efficienza energetica nell'edilizia storica*, in «Materiali e strutture: problemi di conservazione», Vol. 12, 2 (2017), pp. 67–82.

Pracchi, Buda 2018: V. N. Pracchi, A. Buda, *Potentialities and criticalities of different retrofit guidelines in their application on different case studies*, in Proceeding of the 3rd Conference on Energy Efficiency in Historic Buildings (Visby, September 2018), pp. 283–293.

Pracchi, Rosina 2013: V. N. Pracchi, E. Rosina, *Protecting historical buildings is not only a question of respecting their appearance*, in Proceedings of the 3rd European Workshop on Cultural Heritage Preservation (Bozen, September 2013), pp. 211–218.

Renè Di Rocco *et al.* 2023: A. Rene' Di Rocco, D. Bottino-Leone, A. Troi, D. Herrera-Avellanosa, *Application of the Guidelines for the Integration of Photovoltaics in Historic Buildings and Landscapes to Evaluate the Best Practices of the Historic Building Energy Retrofit Atlas*, in «Buildings», Vol. 14, 2 (2024), article n. 499.

Rossetto 2023: N. Rossetto, *Beyond Individual Active Customers: Citizens and Renewable Energy Communities in the European Union*, in «IEEE Power & Energy Magazine», Vol. 21, 4 (2023), pp. 36–44.

Salvia *et al.* 2020: G. Salvia, E. Morello, F. Rotondo, A. Sangalli, F. Causone, S. Erba, L. Pagliano, *Performance Gap and Occupant Behavior in Building Retrofit: Focus on Dynamics of Change and Continuity in the Practice of Indoor Heating*, in «Sustainability», Vol. 12, 14 (2020), article n. 5820.

Schuetze, Chelleri 2016: T. Schuetze, L. Chelleri, *Urban Sustainability Versus Green-Washing. Fallacy and Reality of Urban Regeneration in Downtown Seoul*, in «Sustainability», Vol. 8, 1 (2016), article n. 33.

Shafique *et al.* 2020: M. Shafique, A. Azam, M. Rafiq, M. Ateeq, X. Luo, *An overview of life cycle assessment of green roofs, in Journal of Cleaner Production*, 250 (2020), article n. 119471.

Shrubsole *et al.* 2014: C. Shrubsole, A. Macmillan, M. Davies, N. May, *100 Unintended consequences of policies to improve the energy efficiency of the UK housing stock*, in «Indoor and Built Environment», Vol. 23, 3 (2014), pp. 340-352.

Sigrist 2023: F. Q. Sigrist, *Greenwashing in Architecture and Urban Planning, Master's thesis, Faculty of Built Environment*, Tampere University, Tampere, Finland, 2023. https://urn.fi/URN:NBN:fi:tuni-202304254364 (last accessed: October 2025).

Susca 2019: T. Susca, *Green roofs to reduce building energy use? A review on key structural factors of green roofs and their effects on urban climate*, in «Building and Environment», 162 (2019), article n. 106273.

Volkova *et al.* 2023: A. Volkova, I. Krupenski, N. Kovtunova, A. Hlebnikov, V. Masatin, A. Ledvanov, *Converting Tallinn's historic centre's (Old Town) heating system to a district heating system*, in «Energy», 275 (2023), article n. 127429.

Więckowski, Sałabun 2023: J. Więckowski, W. Sałabun, *Sensitivity analysis approaches in multi-criteria decision analysis: A systematic review*, in «Applied Soft Computing», 148 (2023), article n. 110915.

**Laws, Regulations, Reports and Guidelines**

3encult n.d.: 3encult, *Executive Summary*, n.d. https://cordis.europa.eu/docs/results/260/260162/final1-3encult-publishable-summary.pdf (last accessed: October 2025).

ARES Sardegna - Regional Health Company 2024: ARES Sardegna - Regional Health Company, *Linee guida per l'efficientamento energetico delle strutture del SSR*, 2024. https://www.aressardegna.it/wp-content/uploads/2024/12/450-ALL.pdf (last accessed: October 2025).

Autonomous Region of Sardinia 2008d: Autonomous Region of Sardinia, *Linee guida per l'individuazione degli impatti potenziali degli impianti fotovoltaici e loro corretto inserimento nel territorio*, 2008. https://www.regione.sardegna.it/documenti/1_74_20080624174706.pdf (last accessed: October 2025).

Autonomous Region of Sardinia 2016a: Autonomous Region of Sardinia, *Regional Directives on Energy Performance in Construction. Annex to Resolution GR No 70/11 of 29.12.2016* [*Direttive Regionali in Materia di Prestazione Energetica in Edilizia. Allegato alla Delib.G.R. n. 70/11 del 29.12.2016*], 2016. https://www.ancisardegna.it/wp-content/uploads/2017/01/Allegato-alla-Delib.G.R.-n.-70-11-del-29.12.2016.pdf (last accessed: October 2025).

Autonomous Region of Sardinia 2016b: Autonomous Region of Sardinia, Resolution 29 December 2016, No 70/11, *POR FESR Sardinia 2014 – 2020. Ex ante thematic conditionality 4.1. Approval of regional directives on energy performance in construction* [*POR FESR Sardegna 2014 – 2020. Condizionalità ex ante tematica 4.1. Approvazione delle direttive regionali in materia di prestazione energetica in edilizia*]. https://www.ancisardegna.it/wp-content/uploads/2017/01/DELIBERAZIONE-N.-70-11-DEL-29.12.2016.pdf (last accessed: October 2025).

Autonomous Region of Sardinia 2019: Autonomous Region of Sardinia, *Piano Energetico*

*Ambientale della Regione Sardegna 2015-2030. Primo Rapporto di Monitoraggio*, 2019. https://sardegnaenergia.regione.sardegna.it/documenti/1_461_20190402172433.pdf (last accessed: October 2025).

Baldé *et al.* 2020: C. P. Baldé, M. Wagner, G. Iattoni, R. Kuehr, *In-depth review of the WEEE Collection Rates and Targets in the EU-28, Norway, Switzerland, and Iceland*, Bonn 2020. https://www.scycle.info/wp-content/uploads/2020/11/In-depth-review_WEEE-Collection-Targets-and-Rates_UNITAR_2020_Final.pdf (last accessed: October 2025).

CEN - European Committee for Standardization 2017: CEN - European Committee for Standardization, *EN 16883:2017. Conservation of cultural heritage: Guidelines for improving the energy performance of historic buildings*, Brussels 2017.

Changeworks 2009: Changeworks, *Renewable Heritage. A guide to microgeneration in traditional and historic homes*, Changeworks, Edinburgh 2009. http://hiberatlas.com/smartedit/projects/200/Changeworks%20Renewable%20Heritage.pdf (last accessed: October 2025).

Council of the European Union 2019: Council of the European Union, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: The European Green Deal*, 15051/19, COM(2019) 640 final, Brussels 2019. https://www.consilium.europa.eu/media/47573/st_15051_2019_init_en.pdf (last accessed: October 2025).

Council of the European Union 2020: Council of the European Union, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Renovation Wave for Europe. Greening our buildings, creating jobs, improving lives*, COM(2020) 662 final, Brussels 2020.

Energy & Strategy Group 2024: Energy & Strategy Group, *Electricity Market. Le traiettorie abilitanti la decarbonizzazione del sistema elettrico italiano*, Politecnico di Milano, 2024.

English Heritage 2012: English Heritage, *Energy Efficiency and Historic Buildings. Insulating solid walls*, 2012.

European Commission 2002: European Commission, *Directive 2002/91/EC of the European Parliament and of the Council on the energy performance of buildings*, 2002.

European Commission 2010: European Commission, *Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings (recast)*, 2010.

European Commission 2012a: European Commission, *Energy Efficiency Directive 2012/27/EU*, 2012.

European Commission 2012b: European Commission, *Directive 2012/19/EU on waste electrical and electronic equipment (WEEE),* 2012.

European Commission 2018: European Commission, *Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources*, 2018.

European Commission 2019b: European Commission, *Directive (EU) 2019/944 of the European Parliament and of the Council on common rules for the internal market for electricity and amending Directive 2012/27/EU*, 2019.

European Commission 2020b: European Commission, *Energy communities: an overview of energy and social innovation*, 2020.

European Commission 2024: European Commission, *Directive 2024/1275 of the European Parliament and of the Council on the energy performance of buildings*, 2024.

European Commission 2025: European Commission, *Annex I. Annex to the Communication to the Commission. Approval of the content of the draft Commission Notice providing guidance on new or substantially modified provisions of the recast Energy Performance of Buildings Directive (EU) 2024/1275. Minimum energy performance standards for non-residential buildings and trajectories for progressive renovation of residential buildings (Article 9)*, 2025. https://energy.ec.europa.eu/document/download/205d9030-1a81-4c0e-aa65-af87b7a0b57d_en?filename=Minimum+energy+performance+standards+for+non-residential+buildings+and+trajectories+for+the+progressive+renovation+of+residential+buildings+%28Article+9%29+-+annex+1.pdf (last accessed: October 2025).

Gevorgian *et al.* 2021: A. Gevorgian, S. Pezzutto, S. Zambotti, S. Croce, U. F. Oberegger, R. Lollini, L. Kranzl, A. Mülle, *European Building Stock Analysis. A country by country descriptive and comparative analysis of the energy performance of buildings*, Eurac research, Bozen 2021. https://webassets.eurac.edu/31538/1643788710-ebsa_web_2.pdf (last accessed: October 2025).

Government of Ireland 2023b: Government of Ireland, *Improving Energy Efficiency in Traditional Buildings Guidance for Specifiers and Installers*, 2023. https://assets.gov.ie/static/documents/improving-energy-efficiency-in-traditional-buildings-guidance-for-specifiers-and-insta.pdf (last accessed: October 2025).

Historic England 2020: Historic England, *Know your home, know your carbon. Reducing carbon emissions in traditional homes*, 2020.

Historic England 2025a: Historic England, *Energy Efficiency and Historic Buildings. Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings*, 2025. https://historicengland.org.uk/images-books/publications/energy-efficiency-historic-buildings-ptl/heag014-energy-efficiency-partl-2025/ (last accessed: October 2025).

ICOMOS 2011: ICOMOS, *Guidance on Heritage Impact Assessments for Cultural World Heritage Properties*, 2011. https://publ.icomos.org/publicomos/jlbSai?html=Bur&base=technica&ref=41623&file=262.pdf&path=Guidance_on_heritage_impact_assessments.pdf (last accessed: October 2025).

IEA 2018: IEA, *End-of-Life Management of Photovoltaic Panels: Trends in PV Module Recycling Technologies*, 2018. https://iea-pvps.org/wp-content/uploads/2020/01/End_of_Life_Management_of_Photovoltaic_Panels_Trends_in_PV_Module_Recycling_Technologies_by_task_12.pdf (last accessed: October 2025).

IEA 2024: IEA, *Environmental Life Cycle Assessment of Electricity from PV systems – 2023 data update,* 2024.

IEA SHC 2021: IEA SHC, *Planning energy retrofits of historic buildings EN16883:2017 in practice*, 2021. https://task59.iea-shc.org/Data/Sites/1/publications/D.B3--Handbook.pdf (last accessed: October 2025).

IEA, IRENA - International Renewable Energy Agency 2016: IEA, IRENA - International Renewable Energy Agency, *End-of-Life Management. Solar Photovoltaic Panels,* 2016.

Italian Government 2005: Italian Government, Legislative Decree 19 August 2005, No. 192, *Implementation of Directive (EU) 2018/844, which amends Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, of Directive 2010/31/EU on the energy performance of buildings, and of Directive 2002/91/EC on the energy performance of buildings* [*Attuazione della direttiva (UE) 2018/844, che modifica la direttiva 2010/31/UE sulla prestazione energetica nell'edilizia e la direttiva 2012/27/UE sull'efficienza energetica, della direttiva 2010/31/UE, sulla prestazione energetica nell'edilizia, e della direttiva 2002/91/CE relativa al rendimento energetico nell'edilizia*] , in «Gazzetta Ufficiale della Repubblica Italiana», No. 222, 23 September 2005. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2005;192 (last accessed: October 2025).

Italian Government 2006a: Italian Government, Law 27 December 2006, No. 296, *Arrangements for the formation of the annual and multiannual State budget* [*Disposizioni per la formazione del bilancio annuale e pluriennale dello Stato*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 299, 27 December 2006. https://www.bosettiegatti.eu/info/norme/statali/2006_0296.htm (last accessed: October 2025).

Italian Government 2006b: Italian Government, Legislative Decree 29 December 2006, No. 311, *Corrective and supplementary provisions to Legislative Decree No. 192 of 19 August 2005 implementing Directive 2002/91/EC on the energy performance of buildings* [*Disposizioni correttive ed integrative al decreto legislativo 19 agosto 2005, n. 192, recante attuazione della direttiva 2002/91/CE, relativa al rendimento energetico nell'edilizia*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 26, 1 February 2007. https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2005;192 (last accessed: October 2025).

Italian Government 2009: Italian Government, Presidential Decree 2 April 2009, No. 59, *Implementing regulation of article 4, paragraph 1, letters (a) and (b), of Legislative Decree No. 192 of 19 August 2005, concerning the implementation of Directive 2002/91/EC on the energy performance of buildings* [*Regolamento di attuazione dell'articolo 4, comma 1, lettere a) e b), del decreto legislativo 19 agosto 2005, n. 192, concernente attuazione della direttiva 2002/91/CE sul rendimento energetico in edilizia*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 132, 10 June 2009. https://www.bosettiegatti.eu/info/norme/statali/2009_0059.htm (last accessed: October 2025).

Italian Government 2013a: Italian Government, Decree Law 4 June 2013, No. 63, *Text of Decree-Law No. 63 of 4 June 2013 (in the Official Journal - general series - No. 130 of 5 June 2013), coordinated with Conversion Law No. 90 of 3 August 2013 (in this same Official Journal on page 3), containing: « Urgent provisions for the transposition of Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010, on energy performance in construction for the definition of infringement procedures initiated by the European Commission, as well as other provisions on social cohesion»* [*Testo del decreto-legge 4 giugno 2013, n. 63 (in Gazzetta Ufficiale - serie generale - n. 130 del 5 giugno 2013), coordinato con la legge di conversione 3 agosto 2013, n. 90 (in questa stessa Gazzetta Ufficiale alla pag. 3), recante: «Disposizioni urgenti per il recepimento della Direttiva 2010/31/UE del Parlamento europeo e del Consiglio del 19 maggio 2010, sulla prestazione energetica nell'edilizia per la definizione delle procedure d'infrazione avviate dalla Commissione europea, nonche' altre disposizioni in materia di coesione sociale»*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 181, 3 August 2013. https://www.bosettiegatti.eu/info/norme/statali/2006_0296.htm (last accessed: October 2025).

Italian Government 2013b: Italian Government, Law 3 August 2013, No. 90, *Urgent provisions for the transposition of Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, for the settlement of infringement procedures initiated by the European Commission, as well as other provisions on social cohesion* [*Disposizioni urgenti per il recepimento della Direttiva 2010/31/UE del Parlamento europeo e del Consiglio del 19 maggio 2010, sulla prestazione energetica nell'edilizia per la definizione delle procedure d'infrazione avviate dalla Commissione europea, nonché altre disposizioni in materia di coesione sociale*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 181, 3 August 2013. https://www.bosettiegatti.eu/info/norme/statali/2013_0090.htm (last accessed: October 2025).

Italian Government 2020c: Italian Government, Decree Law 19 May 2020, No. 34, *Urgent measures regarding health, support for work and the economy, as well as social policies related to the COVID-19 health emergency* [*Misure urgenti in materia di salute, sostegno al lavoro e all'economia, nonche' di politiche sociali connesse all'emergenza epidemiologica da COVID-19*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 128, 19 May 2020. https://www.gazzettaufficiale.it/eli/id/2020/05/19/20G00052/sga (last accessed: October 2025).

Italian Government 2020d: Italian Government, *Implementing Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency* [*Attuazione della direttiva (UE) 2018/844 del Parlamento europeo e del Consiglio, del 30 maggio 2018, che modifica la direttiva 2010/31/UE sulla prestazione energetica nell'edilizia e la direttiva 2012/27/UE sull'efficienza energetica*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 146, 10 June 2020.

Italian Government 2021f: Italian Government, Legislative Decree 8 November 2021, No. 199, Implementing Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on promoting the use of energy from renewable sources [*Attuazione della direttiva (UE) 2018/2001 del Parlamento europeo e del Consiglio, dell'11 dicembre 2018, sulla promozione dell'uso dell'energia da fonti rinnovabili*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 285, 30 November 2021.

MASE - Ministry of Environment and Energy Security 2024: MASE - Ministry of Environment and Energy Security, *Identification of an incentive tariff for renewable source systems inserted in renewable energy communities and in single distance and collective self-consumption configurations, in implementation of the legislative decree of 8 November 2021, n. 199, and Mission 2, Component 2, Investment 1.2 of the PNRR* [*Individuazione di una tariffa incentivante per impianti a fonti rinnovabili inseriti in comunità energetiche rinnovabili e nelle configurazioni di autoconsumo singolo a distanza e collettivo, in attuazione del decreto legislativo 8 novembre 2021, n. 199, e della Missione 2, Componente 2, Investimento 1.2 del PNRR*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 31, 7 February 2024.

MiBACT 2015: MiBACT, *Linee di indirizzo per il miglioramento dell'efficienza energetica nel patrimonio culturale. Architettura, centri e nuclei storici ed urbani*, 2015. https://media.cultura.gov.it/mibac/files/boards/388a5474724a15af0ace7a40ab3301de/PDF/Allegato%202%20Linee_indirizzo_miglioramento_efficienza_energetica_nel_patrimonio_culturale.pdf (last accessed: October 2015).

MiC 2024: MiC, Directorate-General of Archaeology, Fine Arts and Landscape, *Energy improvement of historic buildings. Establishment of a community of practice. Appointment of institutional focal points*, Rome 2024. https://dgabap.cultura.gov.it/wp-content/uploads/2024/11/

circolare-miglioramento-energetico-signed.pdf (last accessed: October 2025).

MiC 2025: MiC, Directorate-General of Archaeology, Fine Arts and Landscape, *Queries concerning the application of Legislative Decree 192/2005 […] with specific reference to scope (Art. 3) and the exclusion regime for listed buildings (paras. 3, 3-bis and 3-bis.1)*, Rome 2025. https://dgabap.cultura.gov.it/wp-content/uploads/2025/07/circolare-efficientamento-energetico_signed.pdf (last accessed: October 2025).

National Trust for Historic Preservation 2011: National Trust for Historic Preservation, *The Greenest Building: Quantifying the Environmental Value of Building Reuse*, 2011. https://www.bostonpreservation.org/sites/default/files/2018-07/The_Greenest_Building_Exec_Summary-ilovepdf-compressed.pdf (last accessed: October 2025).

Regional Council of Sardinia 2024: Regional Council of Sardinia, Regional Law 5 December 2024, No. 20, *Urgent measures for the identification of suitable and unsuitable areas and surfaces for installation e promotion of renewable energy source (RES) systems and for the simplification of procedures authorizations* [*Misure urgenti per l'individuazione di aree e superfici idonee e non idonee all'installazione e promozione di impianti a fonti di energia rinnovabile (FER) e per la semplificazione dei procedimenti autorizzativi*]. https://www.consregsardegna.it/wp-content/uploads/2024/12/17-legislatura-LEGGE-REGIONALE-2024-20.pdf (last accessed: October 2025).

RICS - Royal Institution of Chartered Surveyors 2024: RICS - Royal Institution of Chartered Surveyors, *Whole life carbon assessment for the built environment*, 3rd Edition, 2024.

U.S. GBC - U.S. Green Building Council 2024: U.S. GBC - U.S. Green Building Council, *LEED v4.1 Cities and communities: plan and design cities. Getting started guide for beta participants*, 2024. https://www.usgbc.org/sites/default/files/2024-08/LEED-v41-LFC-Plan-and-Design-Cities-Beta-Guide-Feb-2024.pdf (last accessed: October 2025).

### *Heritage context analysis*

#### Bibliography

Brandi 1963: C. Brandi, *Teoria del restauro*, Edizioni di Storia e Letteratura, Rome 1963.

Brogiolo 1988: G.P. Brogiolo, *Archeologia dell'edilizia storica*, Edizioni New Press, Como 1988.

Caniggia, Maffei 2008: G. Caniggia, G. L. Maffei, *Lettura dell'edilizia di base*, Alinea Editrice, Florence 2008.

Carbonara 2004: G. Carbonara, *Atlante del restauro*, UTET, Turin 2004.

Dalla Negra 2013: R. Dalla Negra, *Lo studio dei fenomeni urbani quale premessa per il governo delle trasformazioni dell'edilizia storica (pre-industriale)*, in K. Ambrogio, M. Zuppiroli, *Energia e restauro. Il miglioramento dell'efficienza energetica in sistemi aggregati di edilizia pre-industriale tra istanze conservative e prestazionali*, FrancoAngeli, Milano 2013. pp. 11–15.

Doglioni 1997: F. Doglioni, *Stratigrafia e restauro. Tra conoscenza e conservazione nell'architettura*, Lint Editoriale Associati s.r.l., Trieste 1997.

Fiorani 2019: D. Fiorani, *Il futuro dei centri storici. Digitalizzazione e strategia conservativa*, Edizioni Quasar, Roma 2019.

Fiorani *et al.* 2022: D. Fiorani, M. Acierno, A. Donatelli, S. Curatelli, A. Martello, *Centri storici, digitalizzazione e restauro. Applicazioni e prime normative della Carta del Rischio*, Sapienza University Press, Rome 2022.

Fiorino 2009: D. R. Fiorino, *L'analisi stratigrafica degli elevati alla scala urbana e architettonica*, in G. G. Ortu, A. Sanna (eds.), *Atlante delle culture costruttive della Sardegna. Approfondimenti*, Regione Autonoma della Sardegna – Università degli Studi di Cagliari – DEI Tipografia del Genio Civile, Cagliari 2009, pp. 78–97.

Fiorino 2010: D. R. Fiorino, *La stratigrafia urbana*, in C. Giannattasio & P. Scarpellini (eds.), *Proposte per Stampace: Idee per un piano di conservazione del quartiere storico cagliaritano*, Gangemi Editore, Roma 2010, pp. 69–74.

Fiorino *et al.* 2009: D. Fiorino, C. Giannattasio, G. Vacca, *Documenting the Intangible: a new approach for preserving immaterial aspects of cultural heritage*, in S. Lira et al. (a cura di), *Proceedings of the International Conference on Intangible Heritage. Sharing Cultures 2009*, Atti del convegno (Pico Island, Azores, 30 maggio–1 giugno 2009), Green Lines Institute for Sustainable Development, Barcelos 2009, pp. 655–664.

Harris 1979: E. C. Harris, *Principles of archaeological stratigraphy*, Academic Press Inc, London 1979.

Eskidemir, Kubat 2020: K. Eskidemir, A.S. Kubat, *Urban form and culture: a comparative analysis of Anatolian and Italian towns*, in «Urban Morphology», 24 (2020), pp. 53–69.

Mannoni 1984: T. Mannoni, *Metodi di datazione dell'edilizia storica*, in «Archeologia medievale», XI (1984), pp. 396–403.

Riegl 1997: A. Riegl, *Il culto moderno dei monumenti. Il suo carattere e i suoi inizi*, Neri Pozza, Vicenza 1997.

Strappa 2021: G. Strappa, *Il lotto costruito e la città futura Il problema dell'unità elementare nella lettura e nel disegno della forma urbana*, in «Urban form and design», 16 (2021), pp. 8–11.

#### Laws, Regulations, Reports and Guidelines

Historic England 2016: Historic England, *Understanding Historic Buildings. A Guide to Good Recording Practice*, revised edition, Historic England, Swindon 2016. https://gat04-live-1517c8a4486c41609369c68f30c8-aa81074.divio-media.org/filer_public/1c/94/1c942b62-d945-4bde-b00a-fc0a273d168a/nr83_understanding_historic_buildings-_a_guide_to_good_recording_practice.pdf (last accessed: October 2025)

ICOMOS 1996: ICOMOS, *Principles for the Recording of Monuments, Groups of Buildings and Sites*, ICOMOS, Paris 1996. https://www.icomos.org.tr/Dosyalar/ICOMOSTR_en005776200158738018 2.pdf (last accessed: October 2025).

### *Urban microclimatology*

*General principles*

Bibliography

Aghamolaei *et al.* 2023: R. Aghamolaei, M. M. Azizi, B. Aminzadeh, J. O'Donnell, *A comprehensive review of outdoor thermal comfort in urban areas: Effective parameters and approaches*, in

«Energy & Environment», Vol. 34, 6 (2023), pp. 2204–2227.

American Society of Heating 1989: American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), *ASHRAE handbook. Fundamentals*, ASHRAE, Atlanta 1989.

Bartesaghi Koc *et al.* 2018: C. Bartesaghi Koc, P. Osmond, A. Peters, *Evaluating the cooling effects of green infrastructure: a systematic review of methods, indicators and data sources*, in «Solar Energy», 166 (2018), pp. 486–508.

Bedford 1936: T. Bedford, *The warmth factor in comfort at work: A physiological study of heating and ventilation*, H. M. Stationery Office, London 1936.

Bernabé *et al.* 2015: A. Bernabé, J. Bernard, M. Musy, H. Andrieu, *Radiative and heat storage properties of the urban fabric derived from analysis of surface forms*, in «Urban Climate», 12 (2015), pp. 205–218.

Boyer *et al.* 2011: L. M. Boyer, J. T. Kevern, V. R. Schaefer, *Cyclic Heat Island Impacts on Traditional Versus Pervious Concrete Pavement Systems*, in «Transp. Res. Rec.», 2011, article n. 2240, pp.107–115.

Bröde *et al.* 2012: P. Bröde, D. Fiala, K. Błażejczyk, I. Holmér, G. Jendritzky, B. Kampmann, B. Tinz, G. Havenith, *Deriving the operational procedure for the Universal Thermal Climate Index (UTCI)*, in «International Journal of Biometeorology», LVI (2012), 3, pp. 481–494.

Cao *et al.* 2002: B. Cao *et al.*, *Simulation analysis of the cooling effect of urban water bodies on the local thermal environment*, in «Water», 14 (2022), article n. 3091.

Chandler 1970: T. J. Chandler, *Selected bibliography on urban climate*, World Meteorological Organization (Tech. Note No. 155, WMO No. 276), Geneva 1970.

Chandler 1976: T. J. Chandler, *The climate of towns*, in T. J. Chandler, S. Gregory (a cura di), *The climate of the British Isles*, Longman, London 1976, pp. 307–329.

Chrysoulakis, Grimmond 2016: N. Chrysoulakis, C. S. B. Grimmond, *Understanding and Reducing the Anthropogenic Heat Emission in Urban Climate Mitigation Techniques,* in M. Santamouris, D. Kolokots (eds.), *Understanding and reducing the anthropogenic heat emission,* Routledge, 2016, pp. 27–40.

Chiri, Giovagnorio 2012: G. M. Chiri, I. Giovagnorio, *The Role of the City's Shape in Urban Sustainability*, in «International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies»,Vol. 3, 3 (2012), pp. 245–258.

Coen 2020: D. R. Coen, *The Advent of Climate Science*, in Hans von Storch (ed.), *Climate Science*, Oxford University Press, Oxford 2020.

Collo 1986: A. Collo (ed.), *La città e l'aria*, FrancoAngeli, 1986 Milan.

D'Olimpio 2008: D. D'Olimpio, *La progettazione del microclima urbano: le caratteristiche microclimatiche in ambiente urbano come fattori per la definizione della qualità ecosistemica dei sistemi insediativi*, Kappa, Rome 2008.

De Pascali 2008: P. De Pascali, *Città ed Energia. La Valenza Energetica dell'Organizzazione Insediativa*, Franco Angeli, Milan 2008.

Dirksena *et al.* 2019: M. Dirksena, R.J. Ronda, N.E. Theeuwesc, G.A. Pagani, *Sky view factor calculations and its application in urban heat island studies, in Urban Climate*, 30 (2019), article n. 100498.

Elgendy *et al.* 2025: D. Elgendy, O. Tolba, T. Kamel, *The impact of increasing urban surface albedo on outdoor air and surface temperatures during summer in newly developed areas*, in «Scientific Reports»,15 (2025), article n. 25165.

Erell *et al.* 2014: E. Erell, D. Pearlmutter, D. Boneh, P. B. Kutiel, *Effect of high-albedo materials on pedestrian heat stress in urban street canyons*, in «Urban Climate», 10 (2014), pp. 367–386.

Ferrari *et al.* 2019: A. Ferrari, A. Kubilay, D. Derome, J. Carmeliet, *The Effects of Reflective and Permeable Pavements on the Urban Microclimate*, in Proceedings of the 16th Conference of IBPSA "Building Simulation" (Rome, September 2019), IBPSA, pp. 3217–3225.

Ferrari *et al.* 2020: A. Ferrari, A. Kubilay, D. Derome, J. Carmeliet, *The use of permeable and reflective pavements as a potential strategy for urban heat island mitigation*, in «Urban Climate», 31 (2020), article n. 100534.

Gagge *et al.* 1972: A. P. Gagge, Y. Nishi, R. R. Gonzalez, *Standard Effective Temperature — a single temperature index of temperature sensation and thermal discomfort*, in Atti del Symposium Thermal Comfort and Moderate Heat Stress, CIB Commission W45 (Human Requirements), Building Research Establishment, London 1972, pp. 229–250.

Givoni 1969: B. Givoni, *Man, climate and architecture*, Applied Science Publisher, London 1969. https://archive.org/details/manclimatearchit0002givo/page/24/mode/2up (last access: June 2025).

Heaviside *et al.* 2017: C. Heaviside, H. Macintyre, S. Vardoulakis, *The urban heat island: Implications for health in a changing environment*, in M. J. Nieuwenhuijsen, A. J. De Nazelle (a cura di), *Built environment and health*, «Current Environmental Health Reports», IV (2017), pp. 296–305.

Höppe 1993: P. R. Höppe, *Heat balance modelling*, in «Experientia», XLIX (1993), Birkhauser Verlag, Basel, pp. 741–746.

Horace 1998: Horace, *Epistole*, traduzione di A. Traina, Mondadori, Milano 1998 (opera originale pubblicata ca. 20 a.C.).

Houghton, Yaglou 1923: F. C. Houghton, C. P. Yaglou, *Determining Equal Comfort Lines*, in « J. Am. Soc. Heating and Ventilation in England», 29 (1923), pp. 165–176.

Koenigsberger *et al.* 1973: O. H. Koenigsberger, T. G. Ingersoll, A. Mayhew, S. V. Szokolay, *Manual of tropical housing and building: Part 1 – Climatic design*, Longman, London 1973.

Jacobs *et al.* 2020: C. M. J. Jacobs *et al.*, *Are urban water bodies really cooling?*, in «Urban Climate», 32 (2020), article n. 100607.

Jandaghian *et al.* 2025: Z. Jandaghian, M. Lacasse, A. Gaur, *Solar Reflectance Index of Building Envelope Materials: A Comparative Review of North American and European Standards and Long-Term Performance*, in «Buildings», Vol. 15, 6 (2025), article n. 888.

Jendritzky, Nübler 1981: G. Jendritzky, W. Nübler, *A model analysing the urban thermal environment in physiologically significant terms*, in «Meteorology and Atmospheric Physics», XXIX (1981), 4, pp. 313–326.

Laouadi 2022: A. Laouadi, *A New General Formulation for the PMV Thermal Comfort Index*, in «Buildings», XII (2022), 1572.

Rose, Devadas 2007: A. L. Rose, M. Devadas, *Assessment of Thermal Comfort in Urban Street Canyons*, in Proceedings of the International Conference on Sustainable Building Asia (June 2007, Seoul, Korea), Rotterdam (Netherlands) 2007, pp. 215–220.

Liu *et al.* 2022: S. Liu, Y. Xie, Y. Zhu, B. Lin, B. Cao, N. H. Wong, J. Niu, Z. Fang, D. Lai, W. Liu, J. Wen, D. Mou, H. Tang, Z. Liu, M. Ignatius, *Comparative analysis on indoor and outdoor thermal comfort in transitional seasons and summer based on multiple databases: Lessons learnt from the outdoors*, in «Science of the Total Environment», DCCCXLVIII (2022).

Mandanici *et al.* 2024: E. Mandanici, G. Lo Grasso, M. A. Tini, A. Zanutta, *Estimation of apparent thermal inertia of roofing materials from aerial thermal imagery*, in «Scientific Reports», 14 (2024), article n. 15926.

Miao *et al.* 2020: C. Miao, S. Yu, Y. Hu, H. Zhang, X. He, W. Chen, *Review of methods used to estimate the sky view factor in urban street canyons, Building and Environment*, 168 (2020), article n. 106497.

Oke 1973: T. R. Oke, *City Size and the Urban Heat Island*, in «Atmospheric Environment», 7 (1973), Pergamon Press, pp. 769–779.

Oke 1974: T. R. Oke, *Review of urban climatology, 1968–1973* (Tech. Note No. 134, WMO No. 383), World Meteorological Organization, Geneva 1974.

Oke 1979: T. R. Oke, *Review of urban climatology, 1973–1976* (Tech. Note No. 169, WMO No. 539), World Meteorological Organization, Geneva 1979.

Oke 1981: T. R. Oke, *Canyon geometry and the nocturnal urban heat-island - comparison of scale model and field observations*, in «J. Climatol.», Vol. 1, 3 (1981), pp. 237–254.

Oke 1982: T. R. Oke, *The energetic basis of the urban heat island*, in «Quarterly Journal of the Royal Meteorological Society», CVIII (1982), pp. 1–24.

Oke 1988: T. R. Oke, *Street design and urban canopy layer climate*, in «Energy and Buildings», 11 (1988), pp. 103–113.

Ole Fanger 1972: P. Ole Fanger, *Thermal Comfort*, McGraw-Hill, New York 1972.

Olgyay 1981: V. Olgyay, *Progettare con il clima: un approccio bioclimatico al regionalismo architettonico*, trad. it. a cura di G. Mancuso, Muzzio Editore, Padova 1981 (ed. orig. *Design with Climate*, Princeton University Press, Princeton 1963).

Pickup, de Dear 2000: J. Pickup, R. de Dear, *An Outdoor Thermal Comfort Index (OUT-SET) – Part I – The Model and Its Assumptions*, in R. de Dear, J. Kalma, T. Oke, A. Auliciems (eds.), *Biometeorology and Urban Climatology at the Turn of the Millennium*, World Meteorological Organization, Geneva 2000, pp. 279–283.

Ratti *et al.* 2005: C. Ratti, N. Baker, K. Steemers, *Energy consumption and urban texture*, in «Energy and Buildings», 37 (2005), pp. 762–776

Ren, Mc Gregor 2021: C. Ren, G. Mc Gregor, *Urban Climate Science for Planning Healthy Cities*, Springer Cham, 2021.

Roy *et al.* 2025: T. B. Roy, A. Middey, R. J. Krupadam, *Unveiling the microclimate: A comprehensive review of tools, techniques, and future directions for sustainable cities*, in Building and Environment, 274 (2025), article n. 112726.

Ryu, Baik 2012: Y. H. Ryu, J. J. Baik, *Quantitative Analysis of Factors Contributing to Urban Heat Island Intensity*, in «Journal of Applied Meteorology and Climatology», Vol. 51, 5 (2012), pp. 842–854.

Salamanca *et al.* 2014: F. Salamanca, M. Georgescu, A. Mahalov, M. Moustaoui, M. Wan, *Anthropogenic heating of the urbanenvironment due to air conditioning*, in «J. Geophys. Res. Atmos.», 119 (2014), pp. 5949–5965.

Santamouris *et al.* 2011: M. Santamouris, A. Synnefa, T. Karlessi, *Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions*, in «Solar Energy», Vol. 85, 12 (2011), pp. 3085-3102.

Seneca 2006: Seneca, *Lettere a Lucilio*, traduzione di G. Reale, Bompiani, Milano 2006 (opera originale pubblicata ca. 65 d.C.).

Sun, Chen 2017: R. Sun, L. Chen, *Effects of green space dynamics on urban heat islands: Mitigation and diversification*, Ecosystem Services, 23 (2017), pp. 38–46.

Szokolay 2004: S. V. Szokolay, *Introduction to architectural science. The basis of sustainable design*, Architectural Press, 2004.

Taha 1997: H. Taha, *Urban climates and heat islands: Albedo, evapotranspiration, and anthropogenic heat*, in «Energy Build.», 25 (1997), pp. 99–103.

Vernon, Warner 1932: H. M. Vernon, C. G. Warner, *The influence of the humidity of the air on capacity for work at high temperatures*, in «Journal of Hygiene», Vol. XXXII, 3 (1932), pp. 431–462.

Vu *et al.* 1998: T. C. Vu, T. Asaeda, M. A. Eusuf, *Reductions in air conditioning energy caused by a nearby park*, in «Energy and Buildings», XXIX (1998), 1, pp. 83–92.

Wang *et al.* 2018: J. Wang, Q. Meng, K. Tan, L. Zhang, Y. Zhang, *Experimental investigation on the influence of evaporative cooling of permeable pavements on outdoor thermal environment*, in «Building and Environment», 140 (2018), pp. 184–193.

Zhou *et al.* 2017: B. Zhou, D. Rybski, J. P. Kropp, *The role of city size and urban form in the surface urban heat island*, in «Scientific Reports», Nature, 7 (2017), pp. 1–9.

**Laws, Regulations, Reports and Guidelines**

American Society of Heating 2020: American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), *ANSI/ASHRAE Standard 55-2020: Thermal environmental conditions for human occupancy*, ASHRAE, 2020.

International Organization for Standardization 2005: International Organization for Standardization, *ISO 7730:2005 – Ergonomics of the thermal environment—Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria*, ISO, 2005.

VDI - Verein Deutscher Ingenieure 2008: VDI – Verein Deutscher Ingenieure, *VDI 3787, Part 2: Environmental Meteorology—Methods for the Human-Biometeorological Evaluation of Climate and Air Quality for Urban and Regional Planning—Part 2: Human-Biometeorological Assessment of*

*Heat Stress and Thermal Comfort in Urban and Regional Planning*, Beuth Verlag, Berlin 2008.

*Methods and tools*

### Online resources

ENVI-met 2025: ENVI-met, *Tutorial Section*, n.d. https://envi-met.com/tutorials-overview/ (last accessed: October 2025).

### Bibliography

Abdinoor *et al.* 2025: J. A. Abdinoor, Z. K. Hashim, B. Horváth, S. Zsebő, D. Stencinger, G. Hegedüs, L. Bede, A. Ijaz, I. M. Kulmány, *Performance of Low-Cost Air Temperature Sensors and Applied Calibration Techniques—A Systematic Review*, in «Atmosphere», 16 (2025), article n. 842.

Alves *et al.* 2022: F. M. Alves, A. Gonçalves, M. R. del Caz-Enjuto, *The Use of ENVI-met for the Assessment of Nature-Based Solutions' Potential Benefits in Industrial Parks—A Case Study of Argales Industrial Park (Valladolid, Spain)*, in «Infrastructures», 7 (2022), article n. 85.

Bherwani *et al.* 2020: H. Bherwani, A. Singh, R. Kumar, *Assessment methods of urban microclimate and its parameters: A critical review to take the research from lab to land*, in «Urban Climate», 34 (2020), article n. 100690.

Blocken 2015: B. Blocken, *Computational Fluid Dynamics for urban physics: Importance, scales, possibilities, limitations and ten tips and tricks towards accurate and reliable simulations*, in «Building and Environment», 91 (2015), pp. 219–245.

Bruse, Fleer 1998: M. Bruse, H. Fleer, *Simulating surface–plant–air interactions inside urban environments with a three-dimensional numerical model*, in «Environmental Modelling & Software», 13 (1998), pp. 373–384.

Chapman *et al.* 2017: L. Chapman, C. Bell, S. Bell, *Can the crowdsourcing data paradigm take atmospheric science to a new level? A case study of the Urban Heat Island of London quantified using Netatmo weather stations*, in «International Journal of Climatology», 37 (2017), pp. 3597–3605.

Chen *et al.* 2011: F. Chen, H. Kusaka, R. Bornstein, et al., *The integrated WRF/urban modelling system: development, evaluation, and applications to urban environmental problems*, in «International Journal of Climatology», 31(2) (2011), pp. 273–288.

de Almeida *et al.* 2021: C. R. de Almeida, A. C. Teodoro, A. Gonçalves, *Study of the Urban Heat Island (UHI) Using Remote Sensing Data/Techniques: A Systematic Review*, in «Environments», 8 (2021), article n. 105.

deSouza *et al.* 2025: P. deSouza, P. C. Ibsen, D. M. Westervelt, R. Kahn, B. F. Zaitchik, P. L. Kinney, *A nationwide evaluation of crowd-sourced ambient temperature data*, in «Frontiers in Environmental Science», 13 (2025), article n. 1527855.

Despini *et al.* 2021: F. Despini, C. Ferrari, G. Santunione, S. Tommasone, A. Muscio, S. Teggi, *Urban surfaces analysis with remote sensing data for the evaluation of UHI mitigation scenarios*, in «Urban Climate», 35 (2021), pp. 100761–100773.

Dinić Branković *et al.* 2025: M. Dinić Branković, M. Igić, J. Đekić, M. Ljubenović, *Impact of urban densification on outdoor microclimate and design of sustainable public open space in residential neighborhoods: A study of Niš, Serbia*, in «Sustainability», 17 (2025), article n. 1573.

ENEA - Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile 2024: ENEA - Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile, *Tetti e pareti verdi per edifici. Linee Guida per la Pubblica Amministrazione e gli Enti Territoriali*, 2024.

Fabbri, Costanzo 2020: K. Fabbri, V. Costanzo, *Drone-assisted infrared thermography for calibration of outdoor microclimate simulation models*, in «Sustainable Cities and Society», 52 (2020), article n. 101855.

E. Fiorillo, L. Brilli, F. Carotenuto, L. Cremonini, B. Gioli, T. Giordano, M. Nardino, *Diurnal Outdoor Thermal Comfort Mapping through ENVI-met Simulations, Remotely Sensed and In Situ Measurements*, in «Atmosphere», 14 (2023), article n. 64.

Fu *et al.* 2025: H. Fu, Y. Jiao, L. Deng, W. Wang, *Dynamic impacts of vegetation growth and urban development on microclimate and building energy consumption*, in «Sustainable Cities and Society», 126 (2025), article n. 106382.

Hafner *et al.* 1999: J. Hafner, E. Kidder, *Urban Heat Island Modeling in Conjunction with Satellite-Derived Surface/Soil Parameters*, in «Journal of Applied Meteorology», 38 (1999), pp. 448–465.

Imhoff *et al.* 2010: M. L. Imhoff, P. Zhang, R. E. Wolfe, L. Bounoua, *Remote Sensing of the Urban Heat Island Effect across Biomes in the Continental USA*, in «Remote Sensing of Environment», 114 (2010), pp. 504–513.

Klemas 2015: V. V. Klemas, *Coastal and Environmental Remote Sensing from Unmanned Aerial Vehicles: An Overview*, in «Journal of Coastal Research», 31 (2015), pp. 1260–1267.

Jänicke *et al.* 2021: B. Jänicke, D. Milošević, S. Manavvi, *Review of user-friendly models to improve the urban micro-climate*, in «Atmosphere», 12 (2021), article n. 1291.

Lindberg *et al.* 2008: F. Lindberg, B. Holmer, S. Thorsson, *SOLWEIG 1.0 – Modelling spatial variations of 3D radiant fluxes and mean radiant temperature in complex urban settings*, in «International Journal of Biometeorology», 52 (2008), pp. 697–713.

Lee, Dessler 2024: J. Lee, A. E. Dessler, *Improved surface urban heat impact assessment using GOES satellite data: A comparative study with ERA-5*, in «Geophysical Research Letters», Vol. 51, 1 (2024).

Liu *et al.* 2020: D. Liu, S. Hu, J. Liu, *Contrasting the performance capabilities of urban radiation field between three microclimate simulation tools*, in «Building and Environment», 175 (2020), article n. 106789.

McRae *et al.* 2020: I. McRae, F. Freedman, A. Rivera, X. Li, J. Dou, I. Cruz, C. Ren, I. Dronova, H. Fraker, R. Bornstein, *Integration of the WUDAPT, WRF, and ENVI-met models to simulate extreme daytime temperature mitigation strategies in San Jose, California*, in «Building and Environment», 184 (2020), srticle n. 107180.

Oke 1987: T. R. Oke, *Boundary Layer Climates*, 2nd ed., Routledge, London 1987.

Park *et al.* 2024: K. Park, C, Jun, J. Baik, H. J. Kim, *Urban canyon design with aspect ratio and street tree placement for enhanced thermal comfort: A comprehensive thermal comfort assessment accounting for gender and age in Seoul, Republic of Korea*, in «Buildings», 14 (2024), article n. 2517.

Rasul *et al.* 2017: A. Rasul, H. Balzter, C. Smith, *A Review on Remote Sensing of Urban Heat and Cool Islands*, in «Land», 6 (2017), article n. 38.

Salamanca *et al.* 2010: F. Salamanca, A. Krpo, A. Martilli, A. Clappier, *A new building energy model coupled with an urban canopy parameterization for urban climate simulations — Part I: formulation, verification, and sensitivity analysis*, in «Theoretical and Applied Climatology», 99 (2010), pp. 331–344.

Stathopoulou, Cartalis 2007: M. Stathopoulou, C. Cartalis, *Daytime urban heat islands from Landsat ETM+ and Corine land cover data: An application to major cities in Greece*, in «Solar Energy», 81 (2007), pp. 358–368.

Tominaga *et al.* 2008: Y. Tominaga, A. Mochida, R. Yoshie, H. Kataoka, T. Nozu, M. Yoshikawa, T. Shirasawa, *AIJ guidelines for practical applications of CFD to pedestrian wind environment around buildings*, in «Journal of Wind Engineering and Industrial Aerodynamics», 96 (2008), pp. 1749–1761.

Toparlar *et al.* 2017: Y. Toparlar, B. Blocken, B. Maiheu, G. J. F. van Heijst, *A review on the CFD analysis of urban microclimate*, in «Renewable and Sustainable Energy Reviews», 80 (2017), pp. 1613–1640.

Voogt, Oke 2003: J. A. Voogt, T. R. Oke, *Thermal Remote Sensing of Urban Climates*, in «Remote Sensing of Environment», 86 (2003), pp. 370–384.

Wang *et al.* 2025a: J. Wang, Z. Li, Y. Liang, J. Ke, *An Assessment of the Applicability of ERA5 Reanalysis Boundary Layer Data Against Remote Sensing Observations in Mountainous Central China*, in «Atmosphere», 16 (2025), article n. 1152.

Wang *et al.* 2019: Y. Wang, D. Zhou, Y. Wang, Y. Fang, Y. Yuan, L. Lv, *Comparative study of urban residential design and microclimate characteristics based on ENVI-met simulation*, in «Indoor and Built Environment», 28 (2019), pp. 1200–1216.

Woolley 2003: H. Woolley, *Urban open spaces*, Taylor & Francis, 2003.

Yin *et al.* 2022: S. Yin, F. Wang, Y. Xiao, S. Xue, *Comparing cooling efficiency of shading strategies for pedestrian thermal comfort in street canyons of traditional shophouse neighbourhoods in Guangzhou, China*, in «Urban Climate», 43 (2022), article n. 101165.

Zhao *et al.* 2021: Q. Zhao, Z. Lian, D. Lai, *Thermal comfort models and their developments: A review*, in «Energy and Built Environment», 2 (2021), pp. 21–33.

Zheng *et al.* 2025: J. Zheng, Z. Ou, Y. Xiang, J. Li, B. Zheng, *How can street interface morphology effect pedestrian thermal comfort: A case study of the old town of Changsha, China*, in «Urban Climate», 60 (2025), article n. 102341.

*Applications and experimentations on case studies*

**Bibliography**

Achour-Younsi, Kharrat 2015: S. Achour-Younsi, F. Kharrat, *Outdoor thermal comfort: impact of the geometry of an urban street canyon in a Mediterranean subtropical climate – case study Tunis, Tunisia*, in «Procedia Soc. Behav. Sci.», 216 (2015), pp. 689–700.

Aminipouria *et al.* 2019: M. Aminipouria, A. J. Knudbyb, E. S. Krayenhoffc, K. Zickfelda, A. Middel, *Modelling the impact of increased street tree cover on mean radiant temperature across Vancouver's local climate zones*, in «Urban Forestry & Urban Greening», 39 (2019), pp. 9–17.

Ascione *et al.* 2024: F. Ascione, O. Bottcher, G. Manniti, M. Mastellone, J. Mühle, *The effect of climate change and urbanization on outdoor microclimate: A case study in Berlin*, in «Energy & Buildings», 308 (2024), article n. 114024.

Cárdenas-Jirón *et al.* 2023: L. A. Cárdenas-Jirón, K. Graw, M. Gangwisch, A. Matzarakis, *Influence of street configuration on human thermal comfort and benefits for climate-sensitive urban planning in Santiago de Chile*, in «Urban Climate», 47 (2023), article n. 101361.

Howard 1833: L. Howard, *The Climate of London*, voll. I–III, London 1833.

Huntington 1930: E. Huntington, *Weather and health: A study of daily mortality in New York City* (Bulletin No. 75), National Research Council, Committee on the Atmosphere and Man, 1930.

Liu *et al.* 2022: S. Liu, Y. Xie, Y. Zhu, B. Lin, B. Cao, N. H. Wong, J. Niu, D. Lai, W. Liu, J. Wen, D. Mou, H. Tang, Z. Liu, *Comparative analysis on indoor and outdoor thermal comfort in transitional and summer seasons across five Köppen climate zones,* in «Science of the Total Environment», 848 (2022), article n. 157694.

Matzarakis, Mayer. 1997: A. Matzarakis, H. Mayer, *Heat stress in Greece*, in «International Journal of Biometeorology», XLI, 1 (1997), pp. 34–39.

Pokrývková *et al.* 2021: J. Pokrývková, Ľ. Jurík, L. Lackóová, K. Halászová, R. Hanzlík, M. E. Banihabib, *The Urban Environment Impact of Climate Change Study and Proposal of the City Micro-Environment Improvement*, in «Sustainability», Vol. 13, 8 (2021), article n. 4096.

Schrijvers *et al.* 2016: P. J. C. Schrijvers, H. J. J. Jonker, S. R. de Roode, S. Kenjereš, *The effect of using a high-albedo material on the Universal Thermal Climate Index within a street canyon*, in «Urban Climate», 17 (2016), pp. 284–303.

Shanthi Priya *et al.* 2012: R. Shanthi Priya, M. C. Sundarraja, S. Radhakrishnan, *Comparing the thermal performance of traditional and modern building in the coastal region of Nagappattinam, Tamil Nadu*, in «Indian Journal of Traditional Knowledge», Vol. 11, 3 (2012), pp. 542-547.

Shooshtarian *et al.* 2020: S. Shooshtarian, C. K. C. Lam, I. Kenawy, *Outdoor thermal comfort assessment: A review on thermal comfort research in Australia*, in «Building and Environment», Vol. CLXXVII (2020).

Spagnolo, de Dear 2003: J. Spagnolo, R. de Dear, *A field study of thermal comfort in outdoor and semi-outdoor environments in subtropical Sydney, Australia*, in «Building and Environment», XXXVIII (2003), 5, pp. 721–738.

Tong *et al.* 2017: S. Tong, N. H. Wong, C. L. Tan, S. K. Jusuf, M. Ignatius, E. Tan, *Impact of urban morphology on microclimate and thermal comfort in northern China,* in «Solar Energy», 155 (2017), pp. 212–223.

Tumini, Rubio-Bellido 2016: I. Tumini, C. Rubio-Bellido, *Measuring Climate Change Impact on Urban Microclimate: A Case Study of Concepción*, in «Procedia Engineering», 161 (2016), pp. 2290–2296.

Wargocki *et al.* 1999: P. Wargocki, D. P. Wyon, Y. K. Baik, G. Clausen, P. O. Fanger, *Perceived air quality, sick building syndrome (SBS) symptoms and productivity in an office with two different pollution loads*, in «Indoor Air», IX (1999), 3, pp. 165–179.

*Microclimate mitigation strategies*

### Online resources

Stefano Boeri Architetti 2021: Stefano Boeri Architetti, *Pergola Village Orani*, 2021. https://www.stefanoboeriarchitetti.net/en/project/orani-pergola-village/ (last accessed: October 2025).

### Bibliography

Cortiços *et al.* 2024: N. D. Cortiços, D. Mateus, C. C. Duarte, A. Stefańska, *Enhancing outdoor comfort through tensile membrane structures and pavement surfaces: A case study report in Évora*, Portugal, in «Thermal Science and Engineering Progress», 53 (2024), article n. 102740.

Cuce *et al.* 2025: P. M. Cuce, E. Cuce, M. Santamouris, *Towards sustainable and climate-resilient cities: Mitigating urban heat islands through green infrastructure*, in «Sustainability», 17 (2025), article n. 1303.

Di Giuseppe *et al.* 2021: E. Di Giuseppe, G. Ulpiani, C. Cancellieri, C. Di Perna, M. D'Orazio, M. Zinzi, *Numerical modelling and experimental validation of the microclimaticimpacts of water mist cooling in urban areas*, in «Energy and Buildings», 231 (2021), article n. 110638.

Ferrari *et al.* 2017: S. Ferrari, M. G. Badas, M. Garau, A. Seoni, G. Querzoli, *The air quality in narrow two-dimensional urban canyons with pitched and flat roof buildings*, in «International Journal of Environment and Pollution», 62 (2017), pp. 347–368.

Ferrari, Tendas 2024: S. Ferrari, L. Tendas, *Ventilation and pollutant dispersion in a group of courtyard buildings with a diagonal wind*, in «EPJ Web of Conferences», 299 (2024), article n. 01011.

Garau *et al.* 2019: M. Garau, M. G. Badas, S. Ferrari, A. Seoni, G. Querzoli, *Air exchange in urban canyons with variable building width: A numerical LES approach*, in «International Journal of Environment and Pollution», 65 (2019), pp. 103–124.

Jon *et al.* 2023: K. S. Jon, Y. Luo, C. H. Sin, P. Y. Cui, Y. D. Huang, J. Tokgo, *Impacts of wind direction on the ventilation and pollutant dispersion of 3D street canyon with balconies*, in «Building and Environment», 230 (2023), article n. 110034.

Kumar Donthu *et al.* 2024: E. V. S. K. Kumar Donthu, S. Shashwat, K. T. Zingre, S. Srinivasan, M. P. Wan, *An investigation of globe temperature in street canyons: A scaled model study implementing cool materials*, in «Buildings», 14 (2024), article n. 3054.

Lai *et al.* 2019: D. Lai, W. Liu, T. Gan, K. Liu, Q. Chen, *A review of mitigating strategies to improve the thermal environment and thermal comfort in urban outdoor spaces*, in «Science of the Total Environment», 661 (2019), pp. 337–353.

Manteghi *et al.* 2015: G. Manteghi, H. Bin Limit, D. Remaz, *Water bodies an urban microclimate: A review*, in «Modern Applied Science», 9 (2015), pp. 1–12.

Nardecchia *et al.* 2018: F. Nardecchia, A. Di Bernardino, F. Pagliaro, P. Monti, G. Leuzzi, L. Gugliermetti, *CFD analysis of urban canopy flows employing the V2F model: Impact of different aspect ratios and relative heights*, in «Advances in Meteorology», 2018 (2018), article n. 2189234.

Ng 2010: E. Ng (ed.), *Designing high-density cities for social and environmental sustainability*, Earthscan, 2010.

Oke 2002: T. R. Oke, *Boundary layer climates*, Routledge, 2002.

Peng *et al.* 2022: Z. Peng, Y. Chen, W. Deng, I. Y. F. Lun, N. Jiang, G. Lv, T. Zhou, *An experimental and numerical study of the winter outdoor wind environment in high-rise residential complexes in a coastal city in Northern China*, in «Buildings», 12 (2022), article n. 2011.

Qin *et al.* 2013: J. Qin, X. Zhou, C. Sun, H. Leng, Z. Lian, *Influence of green spaces on environmental satisfaction and physiological status of urban residents*, in «Urban Forestry & Urban Greening», 12 (2013), pp. 490–497.

Santamouris 2014: M. Santamouris, *Cooling the cities: A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments*, in «Solar Energy», 103 (2014), pp. 682–703.

Taleghani, Berardi 2018: M. Taleghani, U. Berardi, *The effect of pavement characteristics on pedestrians' thermal comfort in Toronto*, in «Urban Climate», 24 (2018), pp. 449–459.

Ulpiani 2019: G. Ulpiani, *Water mist spray for outdoor cooling: A systematic review of technologies, methods and impacts*, in «Applied Energy», 254 (2019), article n. 113647.

Watanabe *et al.* 2014: S. Watanabe, K. Nagano, J. Ishii, T. Horikoshi, *Evaluation of outdoor thermal comfort in sunlight, building shade, and pergola shade during summer in a humid subtropical region*, in «Building and Environment», 82 (2014), pp. 556–565.

Xue *et al.* 2015: F. Xue, X. Li, J. Ma, Z. Zhang, *Modeling the influence of fountain on urban microclimate*, in «Building Simulation», 8 (2015), pp. 285–295.

Yang *et al.* 2016: J. Yang, Z. H. Wang, K. E. Kaloush, H. Dylla, *Effect of pavement thermal properties on mitigating urban heat islands: A multi-scale modeling case study in Phoenix*, in «Building and Environment», 108 (2016), pp. 110–121.

Zhang *et al.* 2024: B. Zhang, C. Y. Li, H. Kikumoto, J. Niu, T. K. T. Tse, *Smart urban windcatcher: Conception of an AI-empowered wind-channeling system for real-time enhancement of urban wind environment*, in «Building and Environment», 253 (2024), article n. 111357.

Zhao *et al.* 2024: Y. Zhao, K. Zhao, X. Zhang, Y. Zhang, Z. Du, *Assessment of combined passive cooling strategies for improving outdoor thermal comfort in a school courtyard*, in «Building and Environment», 252 (2024), article n. 111247.

Zuckerman *et al.* 2025: N. Zuckerman, N. Shiloah, I. M. Lensky, *Quantifying the impact of vertical greenery systems (VGS) on Mediterranean urban microclimate during heat wave events*, in «Building and Environment», 267 (2025), article n. 112151.

*Urban microclimate and preexisting and historic urban environments*

### Bibliography

Boeri *et al.* 2023: A. Boeri, D. Longo, K. Fabbri, R. Roversi, S. Boulanger, *The Relation between Outdoor Microclimate and People Flow in Historic City Context the Case Study of Bologna within the ROCK Project*, in «Sustainability», 15 (2023), article n. 7527.

Ciacci *et al.* 2025: C. Ciacci, N. Banti, V. Di Naso, F. Bazzocchi, Evaluating UHI Mitigation and Outdoor Comfort in a Heritage Context: A Microclimate Simulation Study of Florence's Historic Center, in «Sustainability», 17 (2025), article n. 8760.

Cirasa 2011: M. Cirasa, *Recupero degli spazi aperti di relazione nei centri storici minori: aspetti bioclimatici e innovazione tecnologica*, Gangemi Editore, Roma 2011.

Giusti 2012: M.A. Giusti, *Città storica e paesaggio: piani e progetti per il restauro e la sostenibilità*, in M. De Vita (ed.), *Città storia e sostenibilità*, Firenze University Press, Florence 2012, pp. 89–96.

Lyu *et al.* 2024: Y. Lyu, L. Zhang, X. Liu, X. Ma, *Microclimate-Adaptive Morphological Parametric Design of Streets and Alleys in Traditional Villages*, in «Buildings», 14 (2024), article n. 152.

Mandic *et al.* 2024: L. Mandic, A. Đjukic, J. Maric, B. Mitrovic, *A Systematic Review of Outdoor Thermal Comfort Studies for the Urban (Re)Design of City Squares*, in «Sustainability», 16 (2024), article n. 4920.

Marini *et al.* 2007: M. Marini, F. Spanedda, A. Serra, *Strategie di riqualificazione urbana*, in F. Spanedda (ed.), *Energia e insediamento. Una ricerca interdisciplinare per l'applicazione di principi di efficienza energetica nei centri storici*, FrancoAngeli, Milan 2007, pp. 97–127.

Rezaie *et al.* 2025: P. Rezaie, V. P. Lopez-Cabeza, J. Sola-Caraballo, C. Galan-Marin, *Cooling Heritage Scenarios: Transforming Historic Squares for Thermal Comfort*, in «Buildings», 15 (2025), article n. 564.

Rodríguez Maure *et al.* 2022: K. Rodríguez Maure, D. Mora, M. Chen Austin, *Microclimate influence in buildings thermal comfort and energy performance: A numerical assessment of a historical heritage settlement*, in «Novasinergia», Vol. 5, 2 (2022), pp. 132–157.

Salata *et al.* 2016: F. Salata, I. Golasi, R. de Lieto Vollaro, A. de Lieto Vollaro, *Urban microclimate and outdoor thermal comfort. A proper procedure to fit ENVI-met simulation outputs to experimental data*, in «Sustainable Cities and Society», 26 (2016), pp. 318–343.

Soares *et al.* 2021: R. Soares, H. Corvacho, F. Alves, *Summer Thermal Conditions in Outdoor Public Spaces: A Case Study in a Mediterranean Climate*, in «Sustainability», 13 (2021), article n. 5348.

Spanedda 2007a: F. Spanedda (a cura di), *Energia e insediamento. Una ricerca interdisciplinare per l'applicazione di principi di efficienza energetica nei centri storici*, FrancoAngeli, Milan 2007.

Spanedda 2007b: F. Spanedda, *Introduzione*, in F. Spanedda (a cura di), *Energia e insediamento. Una ricerca interdisciplinare per l'applicazione di principi di efficienza energetica nei centri storici*, FrancoAngeli, Milan 2007, pp. 9–12.

Tang *et al.* 2011: L. Tang, M. Nikolopoulou, F. Zhao, N. Zhang, *CFD modeling of built air environment in historic settlements: village microclimate*, Proceedings of the International Conference on Computer Distributed Control and Intelligent Environmental Monitoring (Changsha, February 2011), IEEE, Piscataway 2011, pp. 1086–1092.

Vitiello 2023: M. Vitiello, *Sostenibilità e cura del patrimonio urbano: per un nuovo modello di gestione dell'efficientamento energetico nei centri storici. Un caso studio*, in «Materiali e strutture», Vol. 12, 24 (2023), pp. 69–88.

Wan *et al.* 2025: Z. Wan, H. Liu, Y. Yu, Y. Wu, M. Melchior, P. Martens, T. Krafft, D. Shaw, *How Does Outdoor Spatial Design Shape the Microclimate, Comfort, and Behavior in Traditional Chinese Villages? A Systematic Review Across Scales, Contexts, and Users*, in «Sustainability», 17 (2025), article n. 6960.

Wang *et al.* 2025b: Y. Wang, X. Liu, R. Xie, J. Wang, Q. Dong, W. Yao, D. Li, *Thermal comfort and urban microclimate response: A new thermal environment assessment model for waterfront spaces in historic ancient towns*, in «Energy and Buildings», 331 (2025), article n. 115393.

Xi *et al.* 2019: 20 H. Xi, R. Liu, W. Han, L. Zhang, L. Sun, *Research on Sustainable Design of Regeneration for Traditional Settlement Based on Ecotect Software*, in «E3S Web of Conferences», 136 (2019), article n. 02024.

Xin *et al.* 2022: K. Xin, J. Zhao, T. Wang, W. Gao, *Supporting Design to Develop Rural Revitalization through Investigating Village Microclimate Environments: A Case Study of Typical Villages in Northwest China*», in «Int. J. Environ. Res. Public Health., 19 (2022), article n. 8310.

*Existing Laws and Regulations on Urban Microclimate Assessment*

**Online Resources**

BBC 2013: BBC, *'Walkie-Talkie' skyscraper melts Jaguar car parts*, 2013. https://www.bbc.com/news/uk-england-london-23930675 (last accessed: July 2025)

Cooler World 2025: Cooler World, *Mapa da Ação Climática Municipal* [*Municipal Climatic Action Map*], 2025 https://get2c.pt/cooler-world/mapa-da-acao-climatica-municipal/

City of London 2020: City of London, *City Corporation introduces the world's first development guidelines on thermal comfort*, 2020. https://news.cityoflondon.gov.uk/city-corporation-introduces-the-worlds-first-development-guidelines-on-thermal-comfort/ (last accessed: July 2025)

Climate ADAPT 2020: Climate ADAPT, *Berlin Biotope Area Factor – Implementation of guidelines helping to control temperature and runoff*, 2020. https://climate-adapt.eea.europa.eu/en/metadata/case-studies/berlin-biotope-area-factor-2013-implementation-of-guidelines-helping-to-control-temperature-and-runoff (last accessed: July 2025)

Environment Agency Austria 2023: Environment Agency Austria, *Versiegelung in Österreich und Niederösterreich bezogen auf Wohnbevölkerung und Dauersiedlungsraum- ÖROK 2022* [*Impervious Surface in Austria and Lower Austria in Relation to Resident Population and Built-up Area – ÖROK Monitoring 2022*], 2023. https://umweltbericht.at/versiegelung-in-oesterreich-und-niederoesterreich-bezogen-auf-wohnbevoelkerung-und-dauersiedlungsraum-oerok-2022/ (last accessed: July 2025).

Szöke-Schuller 2023: R. Szöke-Schuller, *SimScale Enables Compliance with City of London Wind Microclimate Guidelines for New Developments*, 2023. https://www.simscale.com/blog/london-wind-microclimate-guidelines/ (last accessed: July 2025)

UNSW - University of New South Wales n.d.: UNSW – University of New South Wales, Sydney, *Built Environment, Microclimate and Urban Heat Island Mitigation Decision-Support Tool (UHI-DS)*, n.d. http://uhimitigationindex.be.unsw.edu.au/uhitool/login.html (last accessed: October 2025)

**Bibliography**

Alcoforado *et al.* 2009: M.J. Alcoforado, A. Saraiva Lopes, J. Vasconcelos, *Application of climatic guidelines to urban planning: The example of Lisbon (Portugal)*, in «Landscape and Urban Planning», 90 (2009), 1–2, pp. 56–65.

Danks *et al.* 2021: R. Danks, R. Shilston, O. Ender, J. Krishan, *Development of the City of London*

*Thermal Comfort Guidelines*, in *Proceedings of Building Simulation 2021 – 17th Conference of IBPSA*, RWDI, Guelph/Milton Keynes (UK) 2021, pp. 1373–1380.

### Laws, Regulations, Reports and Guidelines

Australian Government 2021: Australian Government, *National Climate Resilience and Adaptation Strategy 2021 – 2025. Positioning Australia to better anticipate, manage and adapt to our changing climate*, 2021. https://www.dcceew.gov.au/sites/default/files/documents/national-climate-resilience-and-adaptation-strategy.pdf (last accessed: October 2025)

City of London 2019: City of London, *Wind Microclimate Guidelines for Developments in the City of London*, 2019. https://www.cityoflondon.gov.uk/assets/Services-Environment/wind-microclimate-guidelines.pdf (last accessed: July 2025)

City of London 2020: City of London, *Thermal Comfort Guidelines for Developments in the City of London*, 2020. https://www.cityoflondon.gov.uk/assets/Services-Environment/thermal-comfort-guidelines-for-developments-in-the-city-of-london.pdf (last accessed: July 2025)

City of Vienna 2018: City of Vienna, *Urban Heat Island Strategy*, 2018. https://www.wien.gv.at/umweltschutz/raum/uhi-strategieplan.html (last access: July 2025)

City of Vienna 2020-2021: City of Vienna, *Stadtklimaanalyse Wien – Grundlagen, Ziele und Anwendung in der Stadtentwicklungsplanung* [*Vienna Urban Climate Analysis – Basics, Objectives and Application in Urban Development Planning*], Vienna Department for Urban Development & Planning, 2020–2021. https://www.wien.gv.at/stadtentwicklung/grundlagen/stadtforschung/stadtklimaanalyse.html (last accessed: July 2025).

City of Vienna 2023a: City of Vienna, *Stadt- und Mikroklima* [*Urban and Microclimate*], Vienna Department for Environment and Climate Protection, 2023. https://www.wien.gv.at/umwelt/mikroklima-stadt (last accessed: July 2025)

City of Vienna 2023b: City of Vienna, *Urban Development and Planning* (section 2.3), in *Vienna Climate Guide – Monitoring Climate Adaptation in Vienna*, Vienna Department for Urban Development & Planning / Director's Office for Climate Affairs, 2023. https://www.wien.gv.at/spezial/klimafahrplan-monitoring-en/climate-adaptation/urban-development-and-planning/ (last accessed: July 2025).

City of Vienna 2025: City of Vienna, *Der Wien-Plan Stadtentwicklungsplan 2035* [*The Vienna Plan Urban Development Plan 2035*], 2025. https://www.wien.gv.at/pdf/ma18/wien-plan.pdf (last accessed: July 2025)

Ding *et al.* 2019: L. Ding, H. Petersen, W. Craft, *Microclimate and Urban Heat Island Mitigation Decision-Support Tool (Project Short Report)*, Cooperative Research Centre for Low Carbon Living, UNSW Sydney 2019.

Federal Republic of Germany 2024: Federal Republic of Germany, *Baugesetzbuch* [*Federal Building Code – BauGB*], *§1a: Climate protection in spatial planning*, version in force as of July 2024. https://www.gesetze-im-internet.de/bbaug/__1a.html (last accessed: July 2025).

Hong Kong Green Building Council 2017: Hong Kong Green Building Council, *Guidebook on Urban Microclimate Study*, 2017. https://www.hkgbc.org.hk/eng/engagement/file/UMC_Guidebook_amended_reduced.pdf (last accessed: July 2025)

Municipality of Porto 2025: Municipality of Porto, *Plano Municipal de Ação Climática do Porto 2030* [*Porto 2030 Municipal Climate Action Plan*], 2025. https://ambiente.cm-porto.pt/files/uploads/cms/PMAC%20Porto_%20vers%C3%A3o%20para%20discuss%C3%A3o%20p%C3%BAblica.pdf (last accessed: July 2025).

ÖROK - Österreichische Raumordnungskonferenz 2023: ÖROK – Austrian Conference on Spatial Planning, *Flächeninanspruchnahme und Versiegelung in Österreich. Kontextinformationen und Beschreibung der Daten für das Referenzjahr 2022* [*Land use and soil sealing in Austria. Contextual information and description of the data for the reference year 2022*], Vienna 2023. https://www.oerok.gv.at/fileadmin/user_upload/publikationen/Broschueren/OEROK_Flaecheninanspruchnahme_und_Versiegelung_2022.pdf (last accessed: July 2025).

Jacobi *et al.* 2024: N. Jacobi, A. Jäger, C. Rothballer, F. Reitemeyer, J. Kropp, W. Lexer, A. Storch, D. Fritz, L. Díaz-Bone, D. Corbett, T. Renoux, *Klimaorientierte Stadtentwicklung: Treibhausgasminderungspotenziale in synergetischen Handlungsfeldern* [*Climate-oriented Urban Development: Greenhouse Gas Reduction Potentials in Synergistic Fields of Action*], Umweltbundesamt (Federal Environment Agency), Dessau-Roßlau 2024. https://www.umweltbundesamt.de/sites/default/files/medien/11850/publikationen/20_2024_cc_klimaorientierte_stadtentwicklung.pdf (last accessed: July 2025).

Portuguese Republic 2024: Portuguese Republic, *Climate Framework Law – Law No. 98/2021 of 31 December 2021*, Diário da República, 1st series, no. 251 (31.12.2021), English version published by Bank of Portugal, Lisbon 2024. https://www.bportugal.pt/sites/default/files/documents/2024-07/Law%20N.98-2021_EN.pdf (last accessed: July 2025).

***The Case Study of Osidda, Sardinia (Italy)***

### Online Resources

Autonomous Region of Sardinia 2025a: Autonomous Region of Sardinia, *Sardegna Geoportale*, n.d. https://www.sardegnageoportale.it/ (last accessed: October 2025).

Autonomous Region of Sardinia 2008c: Autonomous Region of Sardinia, *Basic geological map of Sardinia at 1:25,000 scale*, 2008. https://www.sardegnageoportale.it/index.php?xsl=2420&s=40&v=9&c=14479&es=6603&na=1&n=100&esp=1&tb=14401 (last accessed: October 2025).

Autonomous Region of Sardinia 2012: Autonomous Region of Sardinia, *Verifiche dei centri matrice*, last update 2012. https://www.sardegnaterritorio.it/j/v/1123?s=6&v=9&c=7343&na=1&n=10 (last accessed: September 2025).

Calcidrata S.p.A n.d.a: Calcidrata S.p.A., *Nuraminis*, n.d. https://www.calcidrata.com/prodotto/nuraminis/ (last accessed: October 2025).

Calcidrata S.p.A n.d.b: Calcidrata S.p.A., *Nuraminis – Massetto*, n.d. https://www.calcidrata.com/prodotto/nuraminis-massetto/ (last accessed: October 2025).

Copernicus Climate Data Store 2025: Copernicus Climate Data Store, *ERA5 hourly time-series data on single levels from 1940 to present*. 2025. https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels-timeseries (last accessed: October 2025).

Cornaviera n.d.: Cornaviera, *Conduttività termica di materiali da costruzione*, n.d. http://www.cornaviera.it/pagina.asp?codice=conduttivit%E0_materiali (last accessed: October 2025).

EU CAP - European Union Common Agricultural Policy Network n.d.: EU CAP – European

Union Common Agricultural Policy Network, *LEADER Explained*, European Commission, n.d. https://eu-cap-network.ec.europa.eu/get-support/leader/leader-explained_en (last accessed: October 2025).

Infobuild n.d.: Infobuild, *Coppo Sardo*, n.d.: https://www.infobuild.it/wp-content/uploads/Coppo-Sardo.pdf (last accessed: October 2025).

Serra 1981: R. Serra, *Cima, Gaetano*, in *Dizionario Biografico degli Italiani*, Vol. XXV, Istituto della Enciclopedia Italiana, Rome 1981. https://www.treccani.it/enciclopedia/gaetano-cima_%28Dizionario-Biografico%29/ (last accessed: October 2025).

Ubakus n.d.: Ubakus, *U-Wert Rechner (U-value calculator)*, n.d. https://www.ubakus.de/u-wert-rechner/ (last accessed: October 2025).

Weather Spark 2025: Weather Spark, *Condizioni climatiche e meteo medie tutto l'anno a Osidda*, 2025. https://it.weatherspark.com/y/62051/Condizioni-meteorologiche-medie-a-Osidda-Italia-tutto-l'anno (last accessed: October 2025).

## Bibliography

Angioni *et al.* 1997: D. Angioni, S. Loi, G. Puggioni, *La popolazione dei comuni sardi dal 1688 al 1991*, CUEC, Cagliari 1997.

Angius 1852: V. Angius, *Geografia, storia e statistica dell'Isola di Sardegna",* in G. Casalis (ed.) *Dizionario geografico storico-statistico-commerciale degli Stati di S. M. il Re di Sardegna*, Vol. XVIII ter, G. Maspero librajo, Turin 1852.

Barca, Cherchi 2002: S. Barca, A. Cherchi, *Introduction to the geology of Sardinia*, in «Rendiconti della Società Paleontologica Italiana», 1 (2002), pp. 11–34.

Becherini *et al.* 2018: F. Becherini, E. Lucchi, A. Gandini, M. Casado Barrasa, A. Troi, F. Roberti, M. Sachini, M. C. Di Tuccio, L. Garmendia Arrieta, L. Pockelé, A. Bernardi, *Characterization and thermal performance evaluation of infrared reflective coatings compatible with historic buildings*, in «Building and Environment», 134 (2018), pp. 35–46.

Bianco, Cuboni 2009: D. Bianco, F. Cuboni (eds.), *Architetture delle colline e degli altipiani settentrionali: Anglona, Gallura, Goceano, Logudoro, Meilogu, Montacuto, Monteleone, Sassarese*, dei Tipografia del Genio Civile, Università degli Studi di Cagliari – Dipartimento di Architettura, Regione Autonoma della Sardegna, 2009.

Bussa 1985: I. Bussa, *La Relazione di Vincenzo Mameli de Olmedilla sugli Stati d'Oliva (1769): il Ducato del Monteacuto*, in «Quaderni Bolotanesi», XI (1985), pp. 189–260.

Bussa 1987: I. Bussa, *Le rendite feudali dello Stato di Oliva in Sardegna in una relazione di Geronimo de Zabarayn (1701)*, in «Quaderni Bolotanesi», XIII (1987), pp. 413–456.

Carmignani *et al.* 2016: L. Carmignani, G. Oggiano, A. Funedda, P. Conti, S. Pasci, *The geological map of Sardinia (Italy) at 1:250,000 scale*, in «Journal of Maps», 12 (2016), 5, pp. 826–835.

Di Cecilia 1999: L. Di Cecilia, *Osidda piccolo sole*, Delta 3, 1999.

Di Pilla *et al.* 2019: L. Di Pilla, G. Desogus, A. Galatioto, R. Ricciu, *Thermal properties of local Sardinian masonry and insulation materials: experimental assessment on full-scale models*, in «Energy», 5 (2019), WEENTECH Ltd., p. 1–6.

Cherchi 2025: G. Cherchi, *Il borgo autentico di Osidda*, in T. K. Kirova, D. R. Fiorino, G. Cherchi (eds.), *Esplorazioni progettuali sul patrimonio culturale. Esiti degli studi promossi dal Rotary Distretto 2080 con le Università e gli Enti del territorio*, Gangemi, Roma 2025, pp. 126–13.

Cherchi *et al.* 2025: G. Cherchi, A. Santus, D.R. Fiorino, S. Ferrari, *Microclimate Assessment and Outdoor Human Comfort Enhancement of a Historic Village in Sardinia, Italy*, in «Urban Planning», 10 (2025), article n. 10708.

Cherchi, Fiorino 2023: G. Cherchi, D.R. Fiorino, *Strategie per la conservazione e la rivitalizzazione dei centri storici rurali: Il caso del Borgo Autentico di Osidda in Sardegna (Italia)*, in P. A. Cruz Franco, A. Rueda Márquez de la Plata (eds.), *La gestión territorial y el problema de la conservación de los centros históricos y el paisaje*, Dykinson, 2023, pp. 166–177.

Corridore 1902: F. Corridore, *Storia documentata della popolazione di Sardegna*, Carlo Clausen, Turin 1902.

De Luca *et al.* 2023: M. De Luca, N. Ruberti, G. Oggiano, Ph. Rossi, V. Pascucci, L. Casini, *Structure of a Variscan migmatite–granite transition zone (N Sardinia, Italy)*, in «Journal of Maps», 19 (2023), article n. 2182721.

de Zabarayn 1987: G. de Zabarayn, *Relazione fiscale (1701)*, in «Quaderni Bolotanesi», 13 (1987), pp. 413–456.

Fiorani, Cacace 2020: D. Fiorani, C. Cacace, *La Carta del Rischio come strumento di gestione conservativa dei centri storici*, in «ArcHistoR», 13 (2020), pp. 1543–1563.

Fiorino, Grillo 2023: D. R. Fiorino, S. M. Grillo, *Continuità materica e declinazioni costruttive nel patrimonio storico in granito del nord Sardegna*, in «MONÈRE. Rivista dei beni culturali e delle istituzioni politiche», 5(2023), pp. 27–50.

Hersbach *et al.* 2023: H. Hersbach, B., Bell, P., Berrisford, G., Biavati, A., Horányi, J., Muñoz Sabater, J., Nicolas, C., Peubey, R., Radu, I., Rozum, D., Schepers, A., Simmons, C., Soci, D., Dee, J. N. Thépaut, *ERA5 hourly data on single levels from 1940 to present* [Data set], Copernicus Climate Change Service (C3S) Climate Data Store (CDS), 2023.

Manconi 1984: F. Manconi, *Le chiudende in Sardegna: storia e documenti*, Edizioni della Torre, Cagliari 1984.

Monsù Scolaro 2024: A. Monsù Scolaro, *Unfinished works in Sardinia: deepening knowledge of in-between public buildings*, in TECHNE, 28 (2024), pp. 242–250.

Montaldo, Corona 2024: N. Montaldo, R. Corona, *Hydrologic sustainability of a Mediterranean tree-grass ecosystem under climate change*, in «Journal of Hydrology», 641 (2024), article n. 131772.

Mugheddu 2016/2017: G. Mugheddu, *Prestazioni energetiche delle murature in pietra* [Master's thesis], University of Cagliari, Academic Year 2016/2017.

Ormerod, Newton 2005: M. G. Ormerod, R.A. Newton, *Moving beyond accessibility: The principles of universal (inclusive) design as a dimension in nD modelling of the built environment*, in «Architectural Engineering and Design Management», 1 (2005), pp. 103–110.

Souza *et al.* 2024: A. R. Souza, R. C. Veloso, J. Maia, I. Flores-Colen, N. M. M. Ramos, *Durability and performance of opaque high-reflectance envelope systems: A systematic review*, in «Journal of Building Engineering», 98 (2024), article n. 111350.

Sirigu, Montaldo 2022: S. Sirigu, N. Montaldo, *Climate change impacts on the water resources and*

*vegetation dynamics of a forested Sardinian basin through a distributed ecohydrological model*, in «Water», 14 (2022), article n. 3078.

Taramelli 1931: A. Taramelli, *Edizione archeologica della carta d'Italia*, 1931.

Vásquez *et al.* 2020: C. Vásquez, R. D'Alençon, P. P. de la Barra, M. Fagalde, F. Salza, *Hygrothermal Potential of Applying Green Screen Façades in Warm-dry Summer Mediterranean Climates*, in «Journal of Facade Design and Engineering», Vol. 8, 2 (2020), pp. 19–38.

Viry 1957: F. G. Viry, *Relation historique et géographique du Royaume de Sardaigne et des principales îles y adjacentes, faite à la fin de l'année 1746*, in «Nuovo Bollettino Bibliografico Sardo», 13 (1957).

Yuan *et al.* 2024: J. Yuan, Z. Jiao, J. Chai, C. Farnham, K. Emura, *Reflective coatings: Enhancing building performance and sustainability*, in «Nano-Structures & Nano-Objects», 39 (2024), article n. 101296.

Zirottu 2005: G. Zirottu, *Osidda: Dal passato al futuro*, Grafiche Editoriali Solinas, 2005.

### Laws, Regulations, Reports and Guidelines

Autonomous Region of Sardinia 2007: Autonomous Region of Sardinia, *Piano Forestale Ambientale Regionale*Regional Environmental Forestry Plan, 2007. https://www.regione.sardegna.it/documenti/1_73_20080129175640.pdf (last accessed: July 2025)

Autonomous Region of Sardinia 2013c: Autonomous Region of Sardinia, *Regional Landscape Plan. Areas of Historical and Cultural Significance* [*Piano Paesaggistico Regionale. Complessi Territoriali con Valenza Storica Culturale*], 2013.

ISTAT 2024: ISTAT, *La demografia delle aree interne: dinamiche recenti e prospettive future*, Statistica Focus, Rome 2024. https://www.istat.it/wp-content/uploads/2024/07/STATISTICA-FOCUS-DEMOGRAFIA-DELLE-AREE-INTERNE_26_07.pdf (last accessed: October 2025).

Italian Government 1993: Italian Government, Presidential Decree 26 August 1993b, No. 412, *Regulation laying down rules for the design, installation, operation and maintenance of building heating systems for the purpose of reducing energy consumption* [*Regolamento recante norme per la progettazione, l'installazione, l'esercizio e la manutenzione degli impianti termici degli edifici ai fini del contenimento dei consumi di energia*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 242, 14 October 1993. https://www.gazzettaufficiale.it/eli/id/1993/10/14/093G0451/sg (last accessed: October 2025).

Italian Government 2017b: Italian Government, Law 6 October 2017, No. 158, *Measures for the Support and Enhancement of Small Municipalities, as well as Provisions for the Redevelopment and Recovery of their Historic Centres* [*Misure per il sostegno e la valorizzazione dei piccoli comuni, nonché disposizioni per la riqualificazione e il recupero dei centri storici dei medesimi comuni*], in «Gazzetta Ufficiale della Repubblica Italiana», No. 256, 2 November 2017. https://www.gazzettaufficiale.it/eli/id/2017/11/02/17G00171/sg (last accessed: August 2025).

MiC 2021: MiC – Ministry of Culture, *Guidelines on the implementation methods of intervention 2.1 "Attractiveness of villages", M1C3 tourism and culture of the National Recovery and Resilience Plan* [*Linee di indirizzo sulle modalità attuative dell'intervento 2.1 "Attrattività dei borghi", M1C3 turismo e cultura del Piano Nazionale di Ripresa e Resilienza*], 2021. https://media.beniculturali.it/mibac/files/boards/be78e33bc8ca0c99bff70aa174035096/PDF/Avvisi/Borghi/Linee%20di%20indirizzo%20Investimento%202.1-Attrattivita%20Borghi.pdf (last accessed: September 2025).

Municipality of Osidda 2002a: Municipality of Osidda, *Piano particolareggiato del centro storico (Zona "A"). Relazione illustrativa*, Osidda 2002.

Municipality of Osidda 2002b: Municipality of Osidda, *Piano particolareggiato del centro storico (Zona "A")*, Osidda 2002.

Municipality of Osidda 2012: Municipality of Osidda, *Piano Comunale di Protezione Civile*, Osidda 2012.

Municipality of Osidda 2013: Municipality of Osidda, *Piano d'Azione per l'Energia Sostenibile (PAES)*, Osidda 2013.

Municipality of Osidda 2015: Municipality of Osidda, *Piano Particolareggiato del Centro Matrice* (PPCM), Osidda 2015.

### Archive documents

AS-NU 1848: AS-NU – Archivio di Stato di Nuoro, *Fondo cessato catasto. Mappe Osidda (metà 800), foglio 8, frazione M*, cadastral map, 1848.

AS-NU 1939: AS-NU, *Mappe imposte dirette. Osidda, sviluppo A, foglio 5*, cadastral map, 1939.

## Acknowledgements

I would like to express my sincere gratitude to my supervisors and co supervisors for their guidance, careful feedback, and steady support throughout this doctoral journey.
For their help with the bibliography and the state of the art review, I warmly thank Alessandra Battisti, Marta Calzolari, Annamaria Colavitti, Ester Cois, Pietromaria Davoli, Giuseppe Desogus, Andrea Frattolillo, Stefano Pili, and Andrea Porceddu.
For their substantial contributions to the development of the research and to the writing of this thesis, I am grateful to professors at the University of Cagliari, in particular Caterina Giannattasio, Maurizio Memoli, Antonio Pala, and Giuseppina Vacca, and to colleagues Martina Ferraro, Anastasiya Lisouskaya, Elisa Pilia, and Alessandro Santus.
For allowing me to undertake my research experience at University College Dublin, I would like to thank Chiara Cocco, Oliver Kinnane, and Philip Crowe. I also thank Professor Loughlin Kelly and colleagues at University College Dublin, Rola Abu Hilal, Antonije Ćatić, Merlo Kelly, Joselyn Haidee Lopez Pelayo, Ítalo Sousa de Sena, Gloriana Vargas Castro, Stephen Wall, and Thanat Thanapornpakornsin.
I am deeply thankful to the community of Osidda for their availability and generosity, especially Antonella, Gavino, Gianfranco, Maristella, Maurizio, Santina, and the Mayor, Antonio Serafino Doneddu.
I also acknowledge the support of associations and institutions, including Associazione Borghi Autentici, Paolo Giovanni Margaritella, Andrea Porceddu, the State Archives in Nuoro, and all those who contributed in different ways.
For operational help and interdisciplinary scientific support, I thank Alida Favarolo, Giulia Fadda, Irene Massa, Marianna Porcu, Marta Pidia, Michela Monni, and Sandro Murru. For photographic support, I am grateful to Alice Agus and Riccardo Fadda.
Finally, I thank Effort, Grip OCR Cagliari, Riccardo Atzori, Valentino Atzori, Davide Nateri, Paul Lavin, Filippo Puddu, Giangabriele Tortora, my professors, my doctoral colleagues (especially Anna, Erika, Federica, Gianluca, Marco, Martina), and my DICAAR colleagues (especially Elisa and Giulia), as well as everyone who offered me a word of encouragement and comfort over these three years, for their emotional support. Above all, I thank my parents and my family for their constant encouragement.
If I have unintentionally overlooked anyone, I offer my apologies and my sincere gratitude to all who supported me along the way.

## Ringraziamenti

Desidero esprimere la mia sincera gratitudine ai miei relatori e correlatori per la guida, l'attento riscontro e il costante sostegno durante questo percorso di dottorato.
Per l'aiuto con la bibliografia e la revisione dello stato dell'arte, ringrazio Alessandra Battisti, Marta Calzolari, Annamaria Colavitti, Ester Cois, Pietromaria Davoli, Giuseppe Desogus, Andrea Frattolillo e Stefano Pili-
Per i contributi sostanziali allo sviluppo della ricerca e alla stesura di questa tesi, sono grata ai docenti dell'Università di Cagliari, in particolare Caterina Giannattasio, Maurizio Memoli, Antonio Pala e Giuseppina Vacca, e ai colleghi Martina Ferraro, Anastasiya Lisouskaya, Elisa Pilia e Alessandro Santus.
Per avermi consentito di svolgere la mia esperienza di ricerca presso la University College Dublin, desidero ringraziare Chiara Cocco, Oliver Kinnane e Philip Crowe. Ringrazio inoltre il Professor Loughlin Kelly e i colleghi della University College Dublin, Rola Abu Hilal, Antonije Ćatić, Merlo Kelly, Joselyn Haidee Lopez Pelayo, Ítalo Sousa de Sena, Gloriana Vargas Castro, Stephen Wall e Thanat Thanapornpakornsin.
Sono profondamente grata alla comunità di Osidda per la disponibilità e la generosità, in particolare Antonella, Gavino, Gianfranco, Maristella, Maurizio, Santina e il Sindaco, Antonio Serafino Doneddu.
Riconosco inoltre il supporto di associazioni e istituzioni, tra cui l'Associazione Borghi Autentici, Paolo Giovanni Margaritella, Andrea Porceddu, l'Archivio di Stato di Nuoro e tutti coloro che hanno contribuito in modi diversi.
Per l'aiuto operativo e per il supporto scientifico interdisciplinare, ringrazio Alida Favarolo, Giulia Fadda, Irene Massa, Marianna Porcu, Marta Pidia, Michela Monni e Sandro Murru. Per il supporto fotografico, sono grata ad Alice Agus e Riccardo Fadda.
Infine, ringrazio Effort, Grip OCR Cagliari, Riccardo Atzori, Valentino Atzori, Davide Nateri, Paul Lavin, Filippo Puddu, Giangabriele Tortora, i miei professori, i miei colleghi di dottorato (in particolare Anna, Erika, Federica, Gianluca, Marco, Martina) e i miei colleghi del DICAAR (in particolare Elisa e Giulia), così come tutti coloro che in questi tre anni mi hanno offerto una parola di incoraggiamento e conforto, per il loro supporto emotivo.
Soprattutto, ringrazio i miei genitori e la mia famiglia per l'incoraggiamento costante.
Se avessi involontariamente dimenticato qualcuno, porgo le mie scuse e la mia sincera gratitudine a tutti coloro che mi hanno sostenuto lungo il cammino.